Ford's Technical Analysis of NHTSA's April 2001 Research Note on "The Rollover Propensity of Fifteen-Passenger Vans"

NHTSA – FORD Meeting
August 20, 2001

Why are we here?

We are here because of a NHTSA Consumer Advisory on fifteen passenger vans which is apparently based on an April 2001 NHTSA Research Note

How is This NHTSA Research Note Study Being Received?

- Ford is receiving calls from concerned fifteen-passenger van owners
- Personal injury attorneys and their experts are relying on the NHTSA analysis to support their contentions that these vans are defective and unreasonably dangerous
- Personal injury attorneys and their experts are claiming that NHTSA ***has*** adopted a rollover resistance standard based on VDANL simulations and open loop reverse steer maneuvers

Ford's Questions To NHTSA?

- Has the Agency concluded that these vehicles are defective and unreasonably dangerous?
- Does the Agency recommend some field actions by manufacturers of this class of vehicles including Ford?
- Has NHTSA adopted a rollover resistance standard based on VDANL?
- Has NHTSA embraced open loop reverse steer maneuvers as a standard test for rollover resistance?
- Does the NHTSA understand how their research note is being misused?

Ford's Conclusions

- Ford disagrees with the adoption of a computer simulation model such as VDANL as a method by which vehicle dynamic performance can be measured and regulated
- Validation experiments confirm that VDANL is not a valid predictor of actual vehicle performance, especially in severe handling maneuvers
- Ford disagrees with the use of open loop maneuvers such as slowly increasing steer and reverse steer maneuvers as a standard by which a vehicle's resistance to rollover can be regulated unless they achieve acceptable reliability, repeatability,objective metrics, and relevance to causes, conditions, and circumstances of crashes.

Who Manufacturers 15 Passenger Vans in the U.S.?

Ford Motor Company

General Motors Corporation

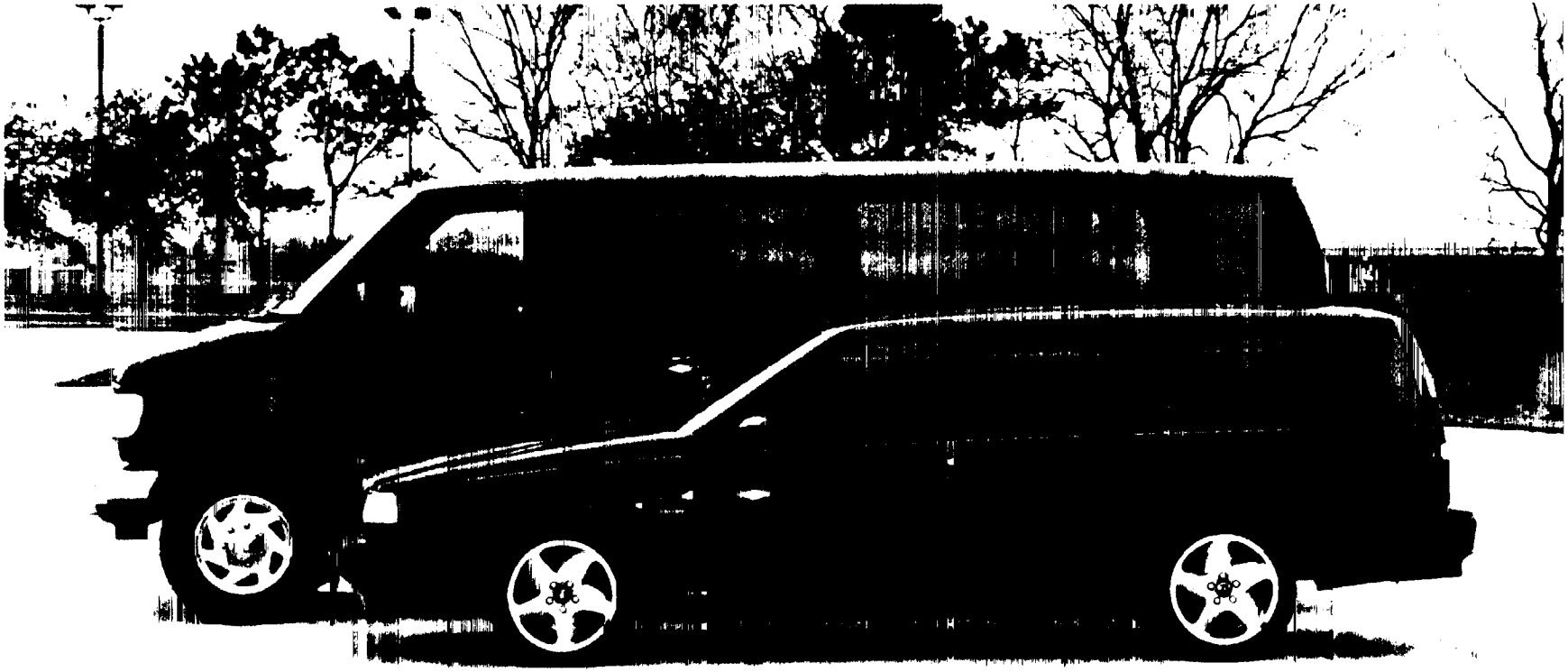
Daimler/Chrysler

Fifteen-Passenger Vans Are Not Passenger Cars and Will Not Steer And Handle Like a Passenger Car

- They have a specific mission and capacity to haul up to fifteen people.
- To accommodate these loads (over 9000 pounds), these vans have truck-type heavy-duty suspensions They also have taller and stronger frames
- They have larger, high load range LT tires at relatively high recommended operating pressures to accommodate expected loads
- The body sits higher off the ground to and to allow larger and stronger chassis components
- They have a level floor to accommodate walk-in ingress and egress
- They don't look or handle like passenger cars

A Fifteen-Passenger Van is Not a Car

A Fifteen-Passenger Van is Not a Car



NHTSA's Research Note Considered Two Measures of Rollover Resistance of Fifteen-Passenger Vans

- Measurement of the Static Stability Factors (SSF) of a fifteen-passenger van, a seven-passenger van, and a minivan
- A VDANL simulation of the handling characteristics of an unloaded and loaded fifteen-passenger van.

NHTSA's Research Note Considered Two Measures of Rollover Resistance of Fifteen-Passenger Vans

- **Measurement of the Static Stability Factors (SSF) of a fifteen-passenger van, a seven-passenger van, and a minivan**
- A VDANL simulation of the handling characteristics of an unloaded and loaded fifteen-passenger van.

NHTSA Compared The SSF of Three Vans

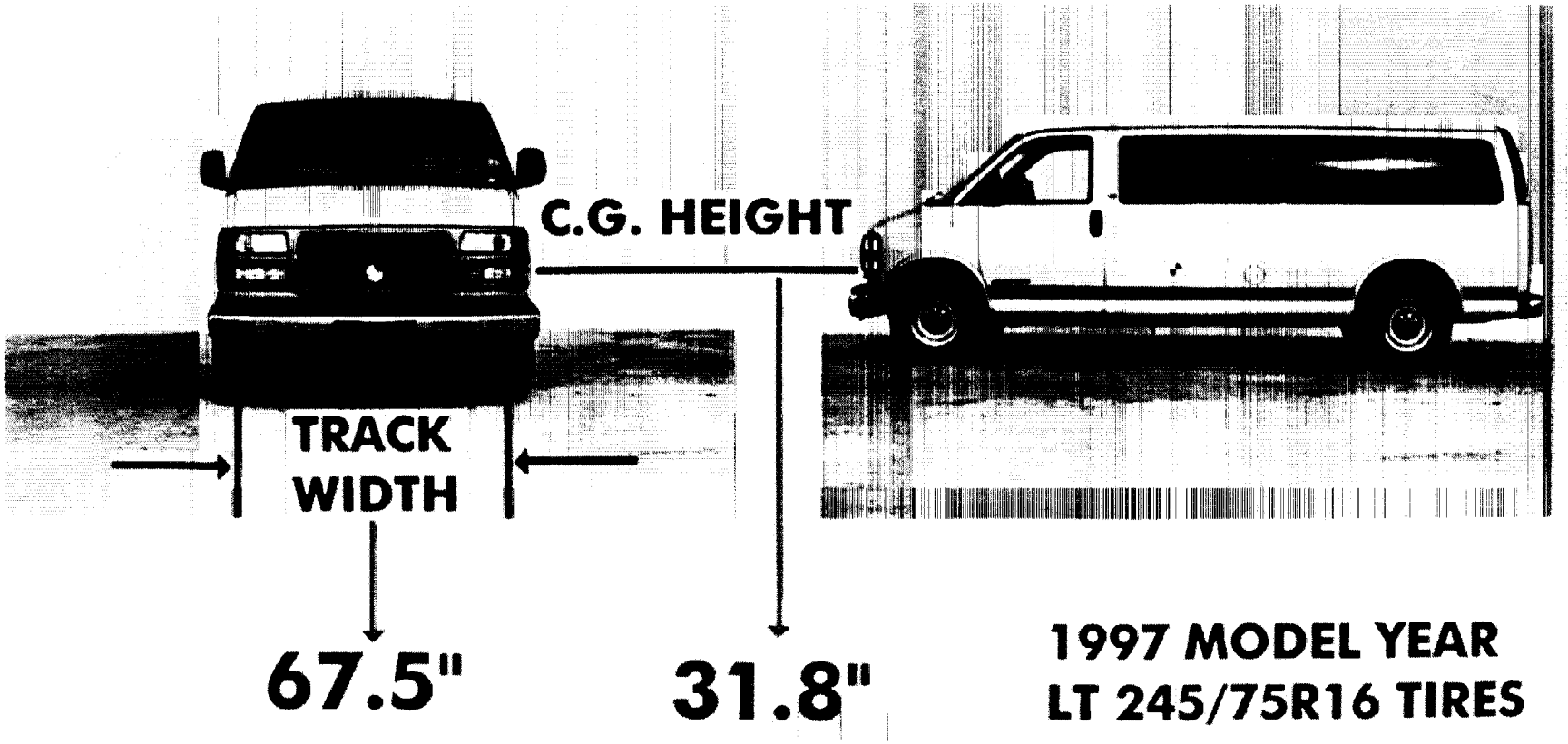
A Ford fifteen-passenger van

A Ford seven passenger van

A Dodge minivan

The Center of Gravity Height, Track Width, and SSF of the Ford Fifteen-Passenger Van is Similar to It's Peers

GMC C-3500
15 PASSENGER VAN



1997 MODEL YEAR
LT 245/75R16 TIRES

DODGE RAM 3500 VAN

65.1"

31.3"

1997 MODEL YEAR
LT245/75R16 TIRES

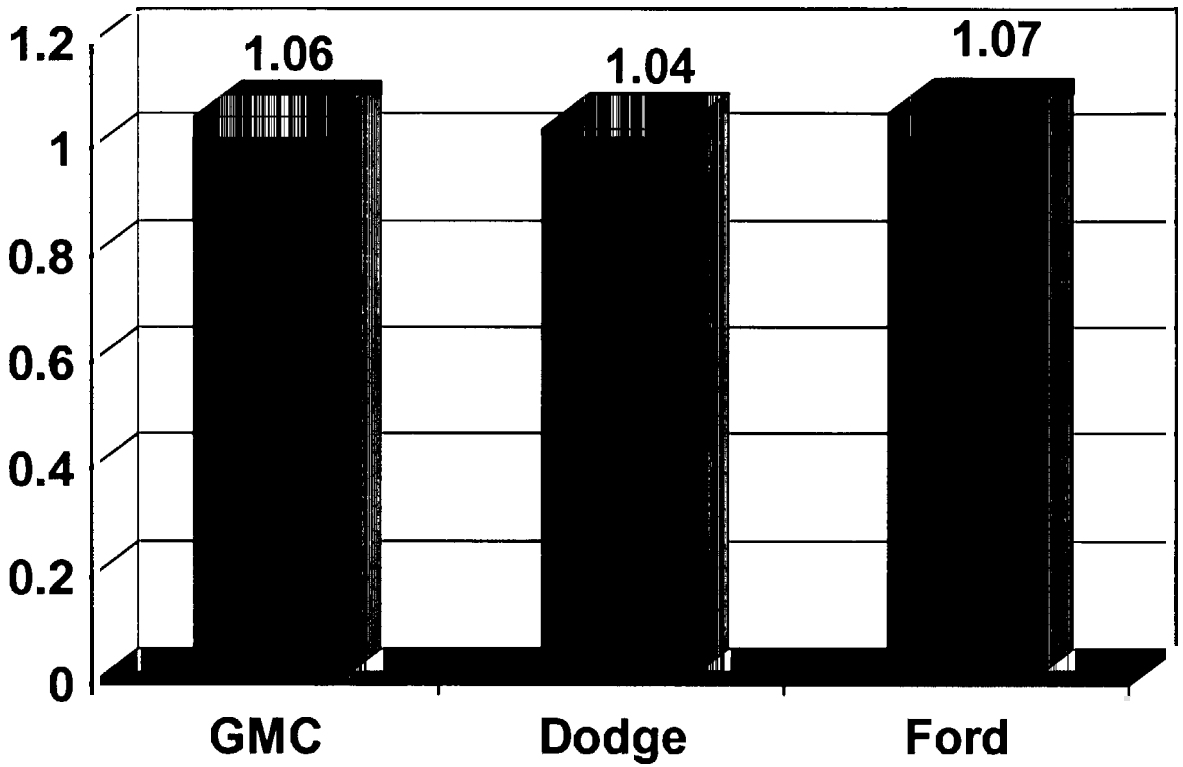
FORD E-350
15 PASSENGER VAN

68.0"

31.8"

1996 MODEL YEAR
LT 245/75R16 TIRES

SSF of Fifteen-Passenger Vans (Curb Load)



Ford's Analysis Indicates That the SSF of the Ford Fifteen-Passenger Van is Comparable to It's Peers When Fully Loaded

NHTSA's Research Note Considered Two Measures of Rollover Resistance of Fifteen-Passenger Vans

- Measurement of the Static Stability Factors (SSF) of a fifteen-passenger van, a seven-passenger van, and a minivan
- **A VDANL simulation of the handling characteristics of an unloaded and loaded fifteen-passenger van.**

NHTSA Performed Computer Simulations to "…Show the Effects of Occupant Loading on the Handling of Fifteen-Passenger Vans." The Simulation Model Used was Vehicle Dynamics Analysis, Non-Linear ("VDANL")

The NHTSA Simulations Do Not Reflect Real World Performance of a Fifteen-Passenger Van. However, They Are Being Used to Show Design Defects in This Class of Vehicle.

What is VDANL?

- Vehicle Dynamics Analysis, Non-Linear
- Original version developed in mid 1980's
- Lumped-parameter vehicle dynamics model
- Marketed and sold by Systems Technology Inc.
- Currently used in matters of litigation by experts retained by personal injury attorneys whose experts run simulations to show purported rollover resistance defects in vehicle designs.

VDANL Vehicle Model Assumptions

- 17 degrees of freedom
- All independent suspensions act as swing axle suspensions
- All dependent suspensions act as rigid axles pinned at the center of the vehicle
- Dependent suspensions have a single roll axis
- All springs are linear in rate
- All shock absorbers are linear in damping
- Front and rear jounce bumpers have same travel and same stiffness

How Does A Ford Fifteen-Passenger Van Conform to These VDANL Vehicle Model Assumptions?

- The van has more than 17 degrees of freedom
- Rear leaf springs are nonlinear in rate
- Rear suspension does not have a fixed roll axis
- Front and rear jounce bumpers have vastly different travels and rates

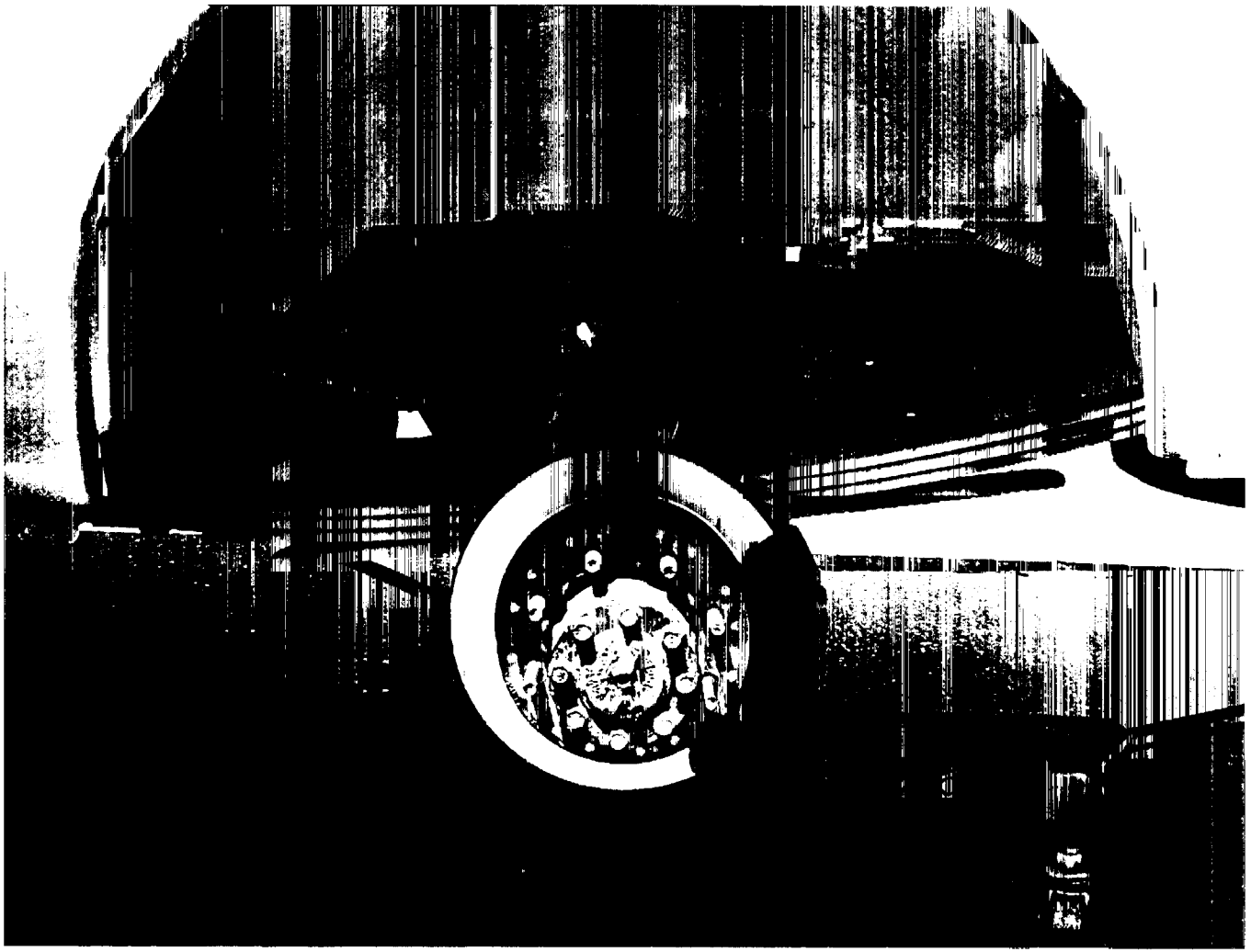
VDANL Tire Model Assumptions

- All tire behavior can be described by the rigid Calspan coefficients developed in the 1970s
- Coefficients do not tell user when tire model is extrapolating beyond measured ranges
- Tires assumed to operate on a surface of uniform and known coefficient of friction
- Tires operate on perfectly smooth surface with continuous and constant coefficient of friction

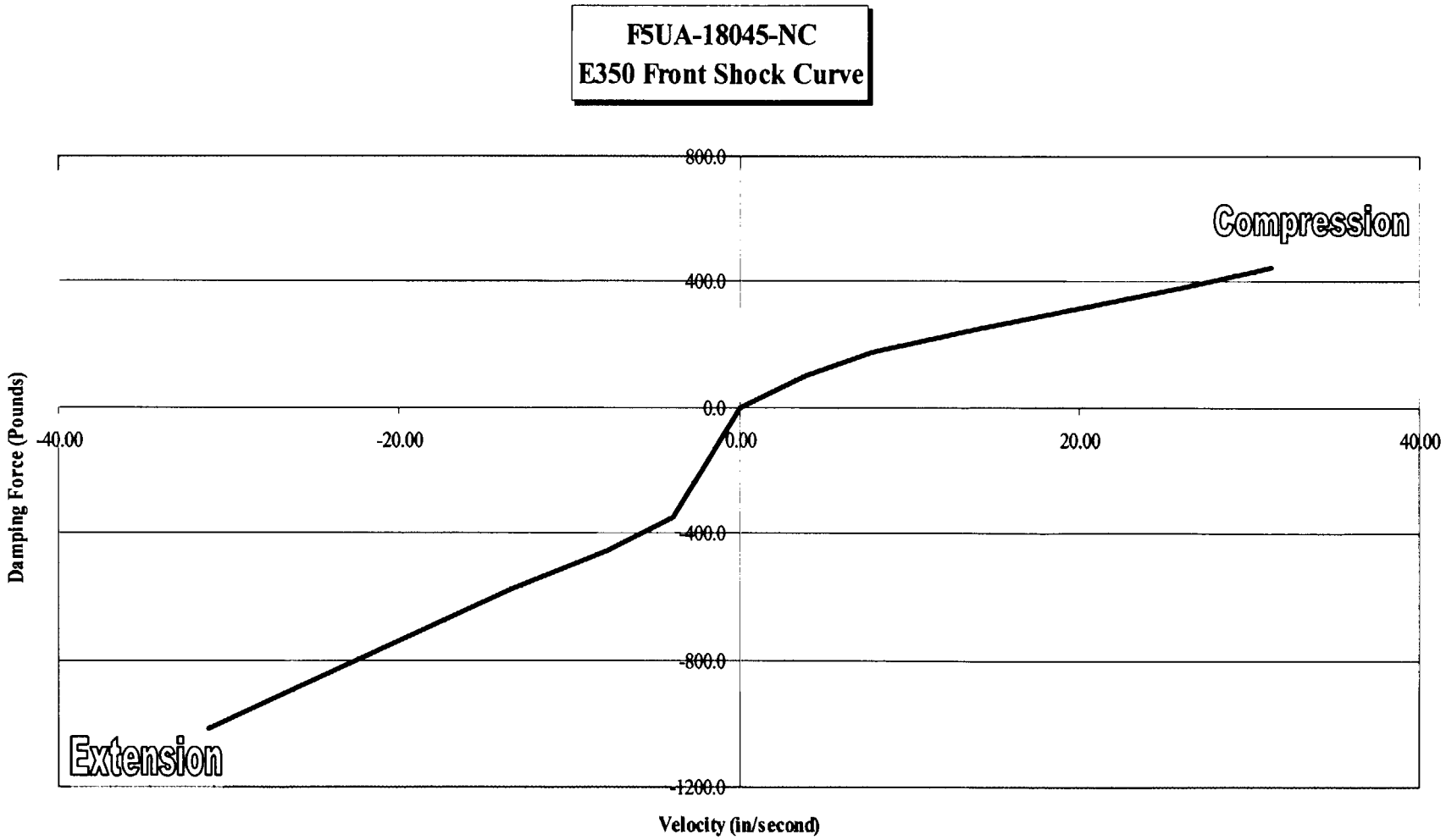
How Do The Tires of a Ford Fifteen-Passenger Van Conform to The VDANL Tire Model Assumptions?

- Tires do not operate on perfectly smooth surfaces of constant coefficient of friction
- Real tires wear
- Real tires do not conform to the simplistic assumptions of the Calspan coefficients
- Is tire data being extrapolated in simulations?

Rear Suspension of Ford E-350 Fifteen-Passenger Van Has Nonlinear Springs



Ford E-350 Fifteen-Passenger Vans, Like All Vehicles, Have Nonlinear Shock Absorbers



Known VDANL Evaluations For Validity

- Systems Technology, Inc. for NHTSA contract DTNH22-88-C-07384 and is described in STI report 1268-1
- Chrstos and Heydinger in 1997 and is described in SAE paper 970566
- Heydinger in 1997 and is described in "Evaluation of VDANL for Predicting Limit Performance of a 1996 Isuzu Trooper"
- NHTSA in 1997 and is described in Petition Analysis DP96-011
- Carr Engineering, Inc.

Evaluation of VDANL Validity by STI

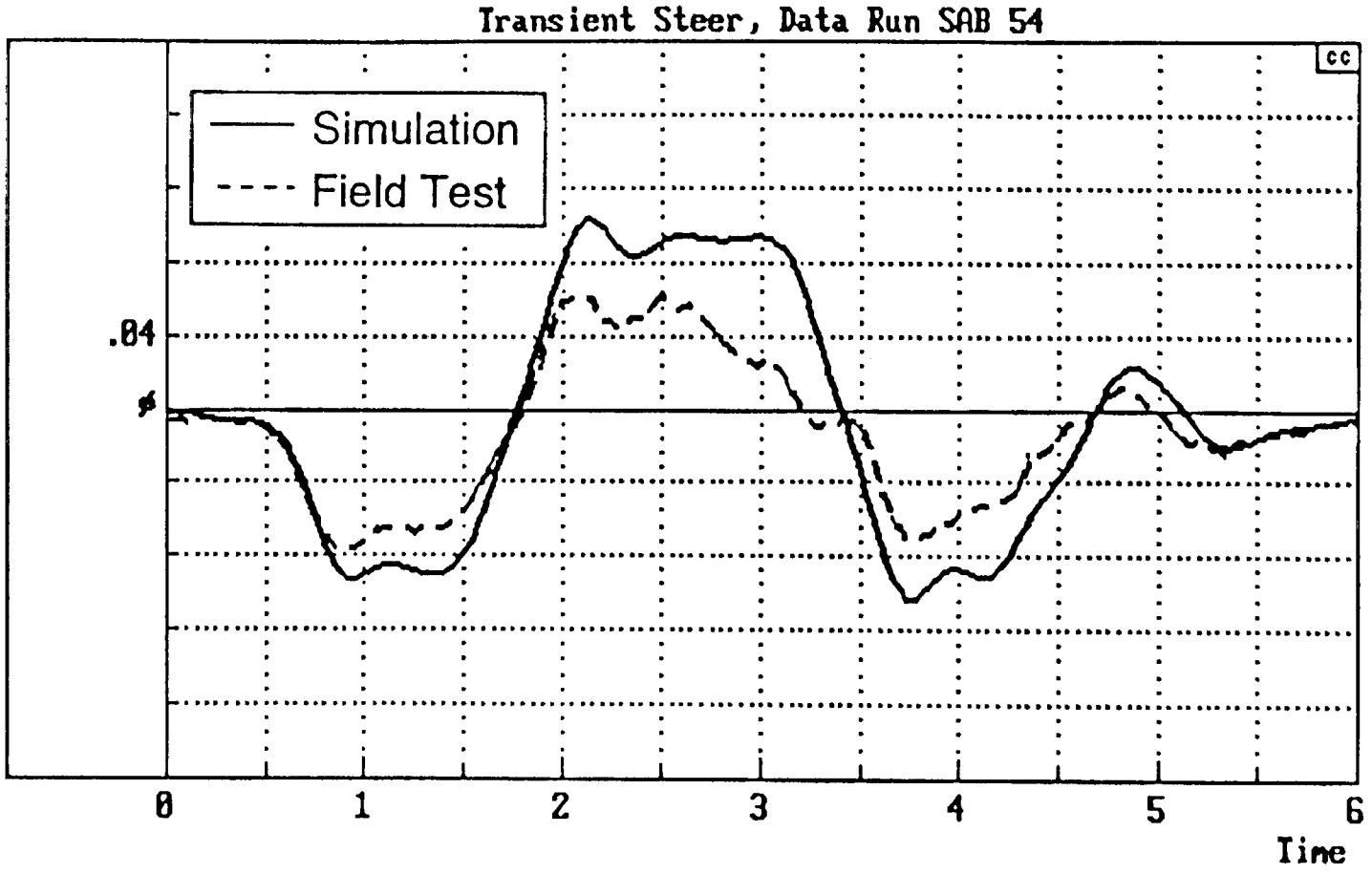
- Vehicle parameters were measured (or estimated) for 41 vehicles
- 12 of those vehicles were tested with 3 tests (constant radius, random steer, open loop lane change) and data was compared to VDANL simulation predictions
- No heavy duty light trucks or fifteen-passenger vans were included
- "For safety reasons, vehicle testing was not designed to induce loss of control or rollover"

Evaluation of VDANL Validity by STI

- Data do not correlate to predictions at limit
- In two cases, VDANL was not predicting vehicle spinouts which occurred in the actual testing so the authors "adjusted" **only** the rear tire data by reducing the coefficient of friction by 15%
- "Given the steady state and dynamic response validation noted above, the transient comparison suggest a valid computer simulation that can be used for **near** limit performance maneuvering analysis…"

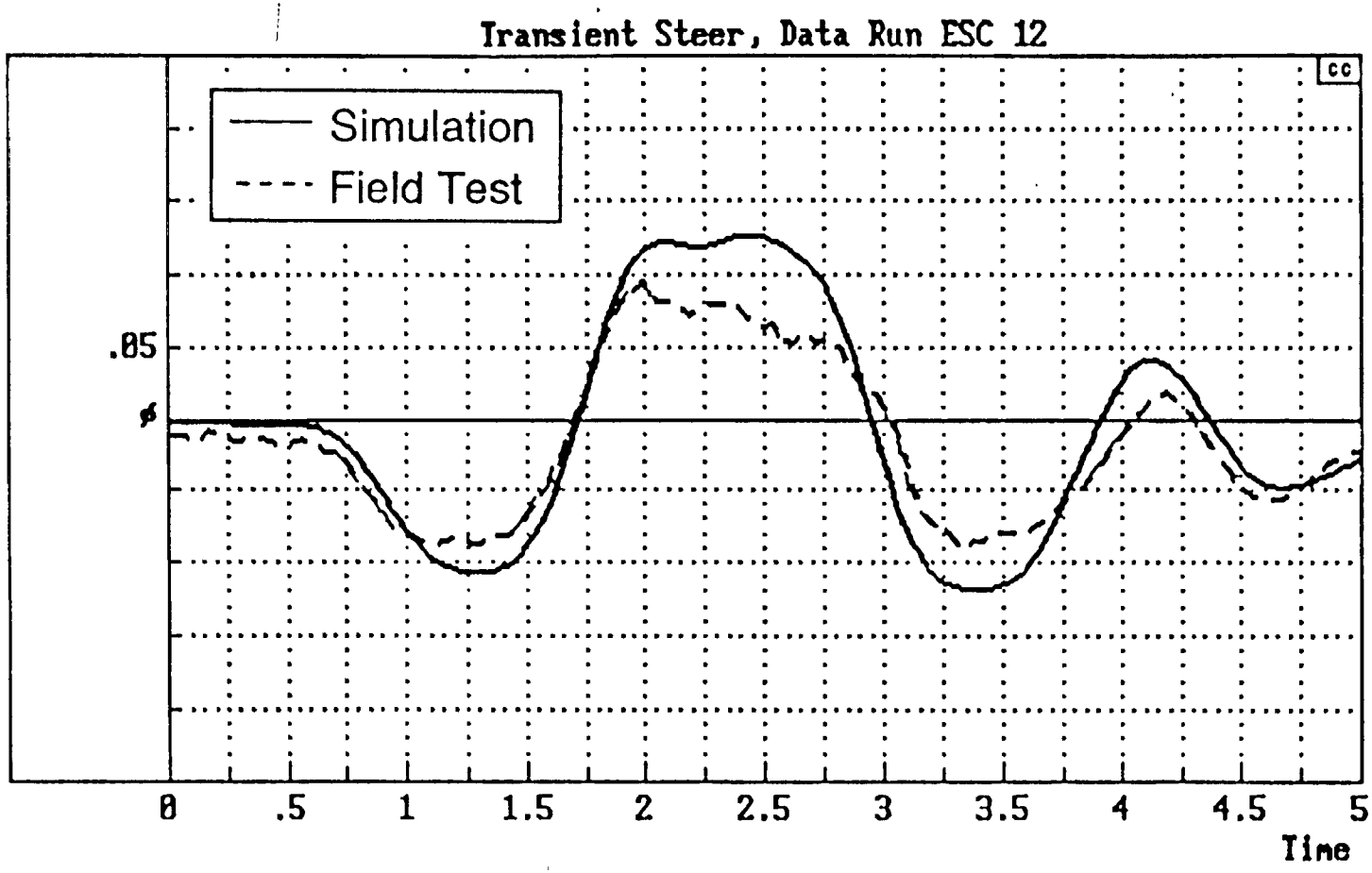
Evaluations of VDANL Validity by STI

Roll Angle of Buick LeSabre



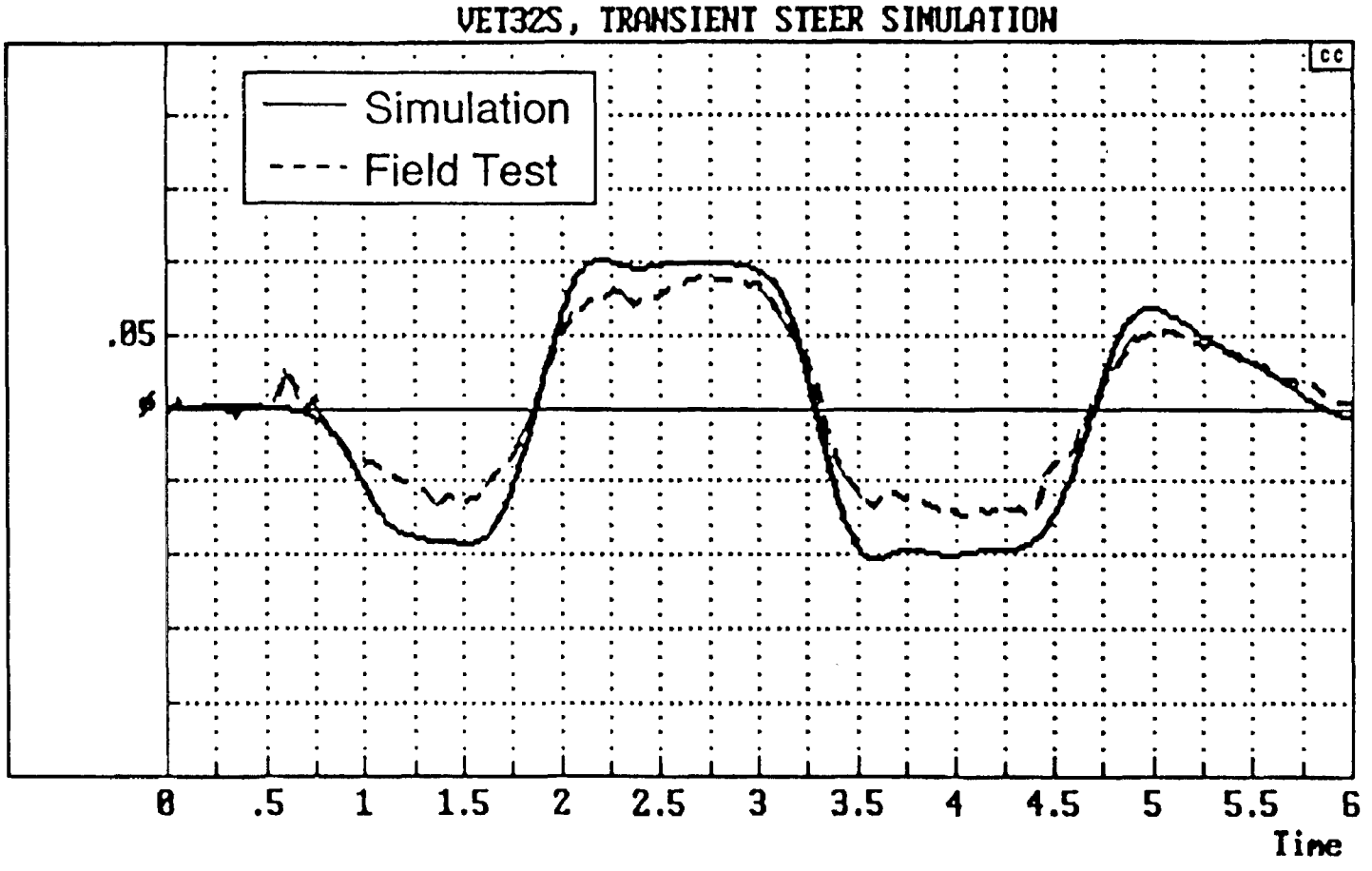
Evaluation of VDANL Validity by STI

Roll Angle of Ford Escort



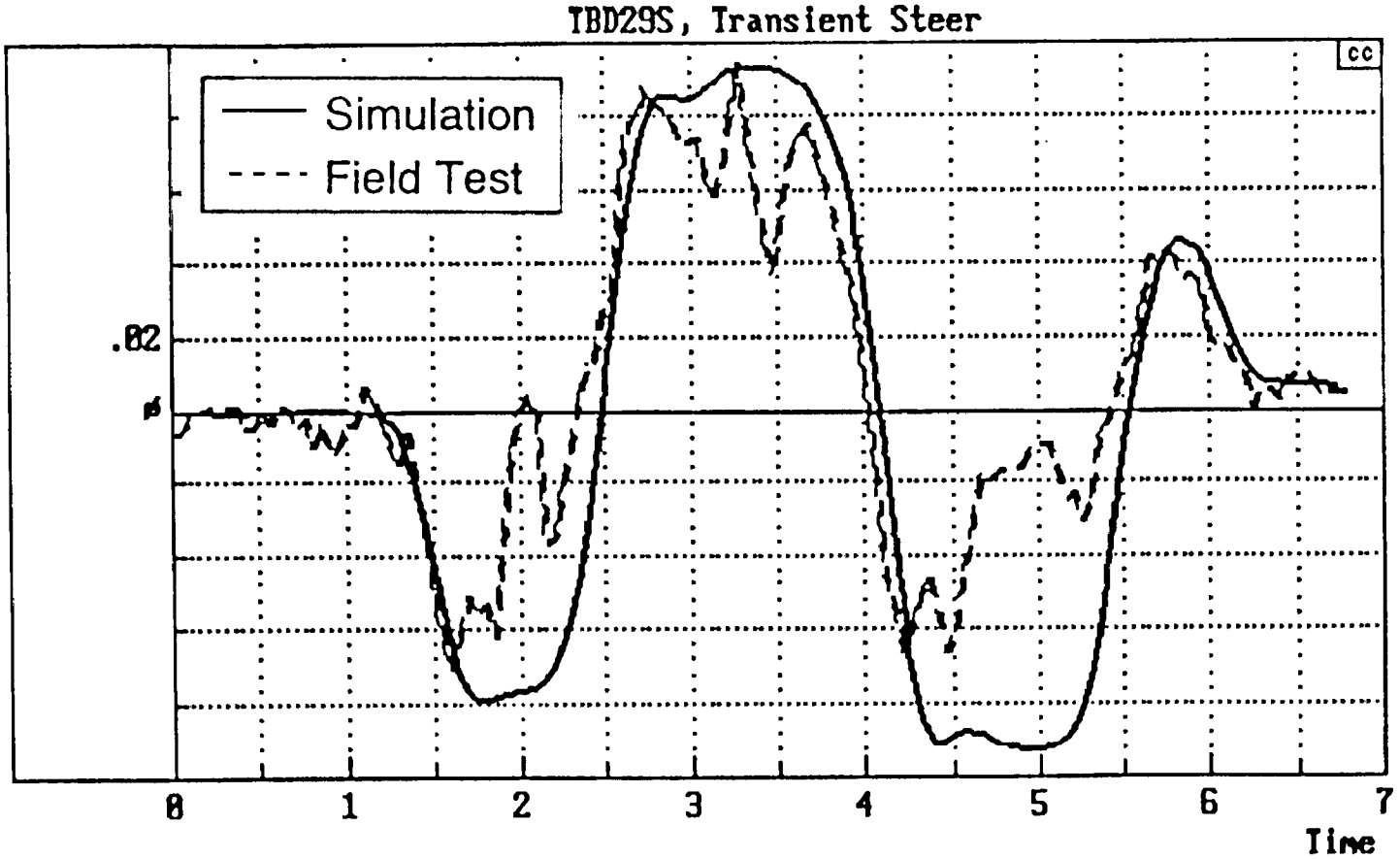
Evaluation of VDANL Validity by STI

Roll Angle of Chevrolet Chevette



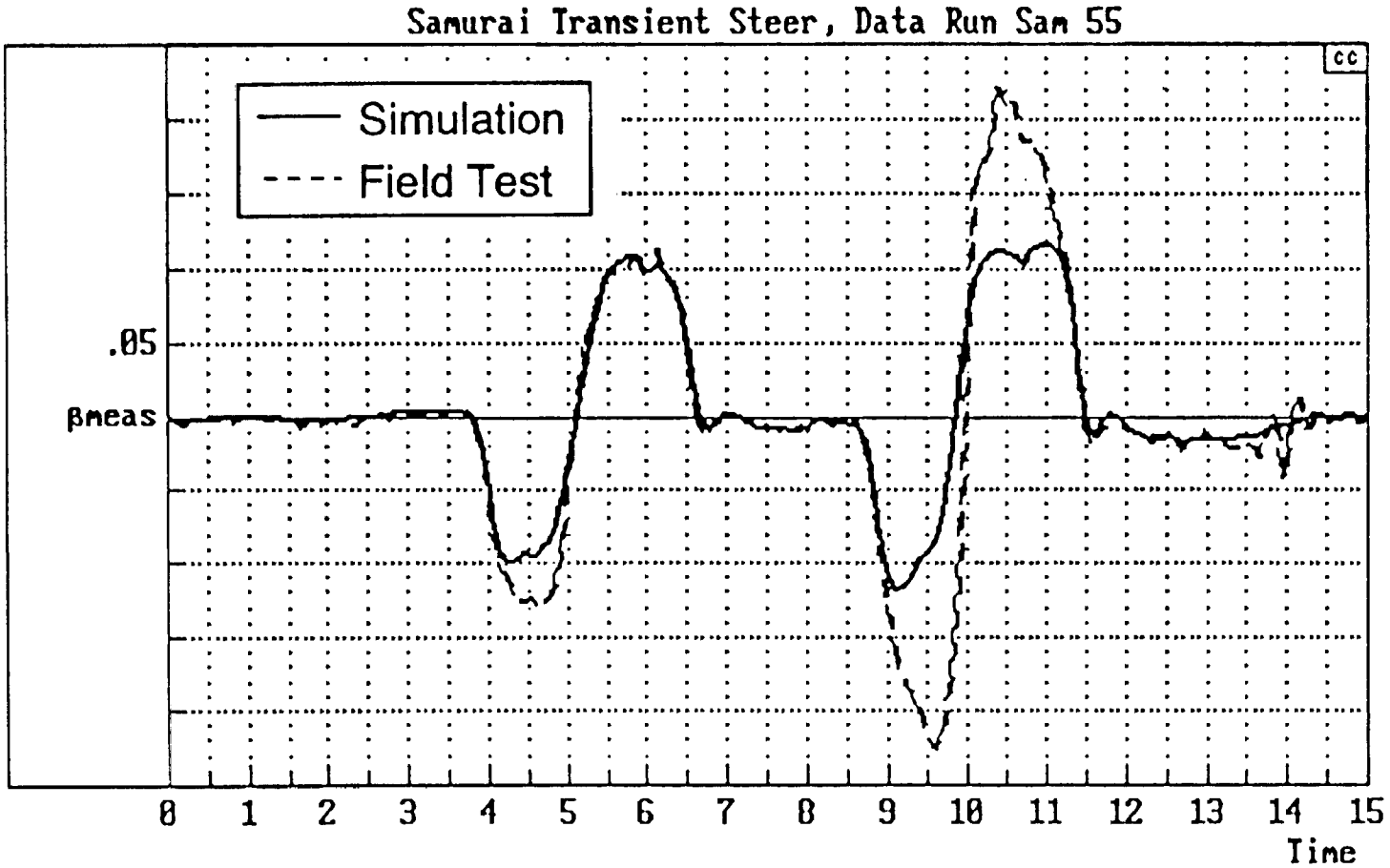
Evaluation of VDANL Validity by STI

Roll Angle of Ford Thunderbird



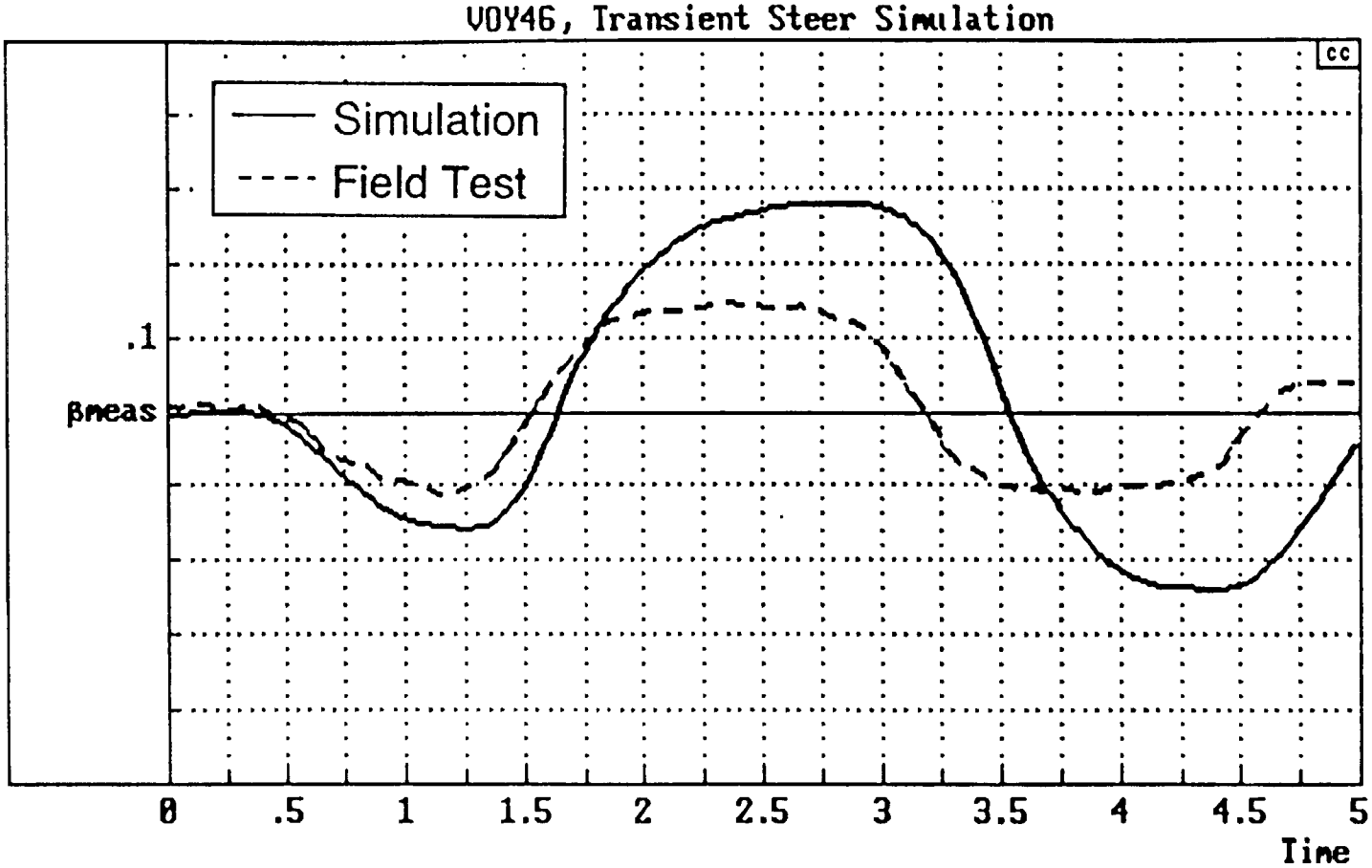
Evaluation of VDANL Validity by STI

Sideslip Angle of Suzuki Samurai



Evaluation of VDANL Validity by STI

Sideslip Angle of Plymouth Voyager



Evaluation of VDANL Validity by Chrstos and Heydinger

- 1994 Ford Taurus passenger car
- VDANL does "…a good job of predicting expected vehicle responses in the linear range."
- No limit performance or rollover validation was performed as part of this study

Evaluation of VDANL Validity by Chrstos and Heydinger

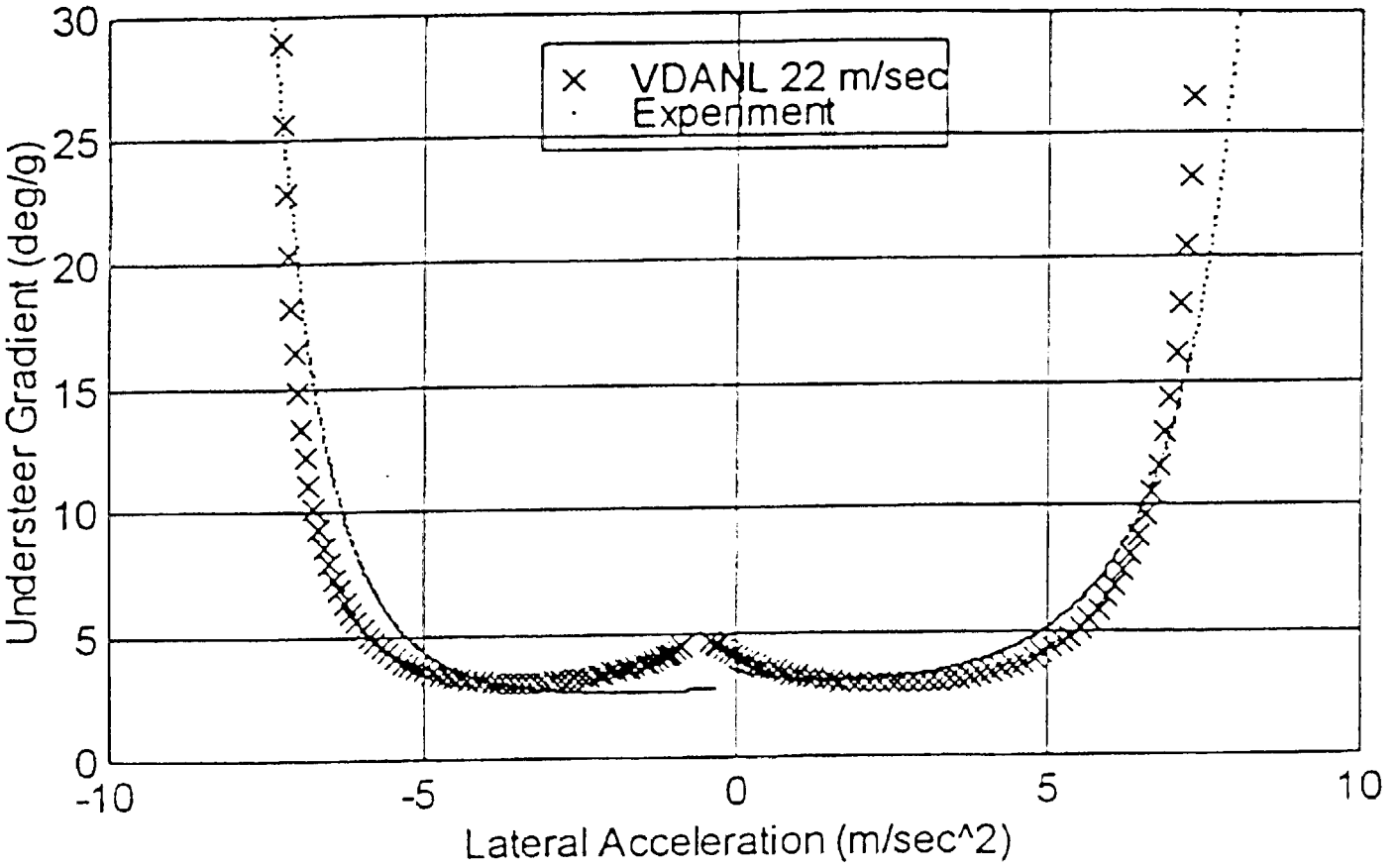


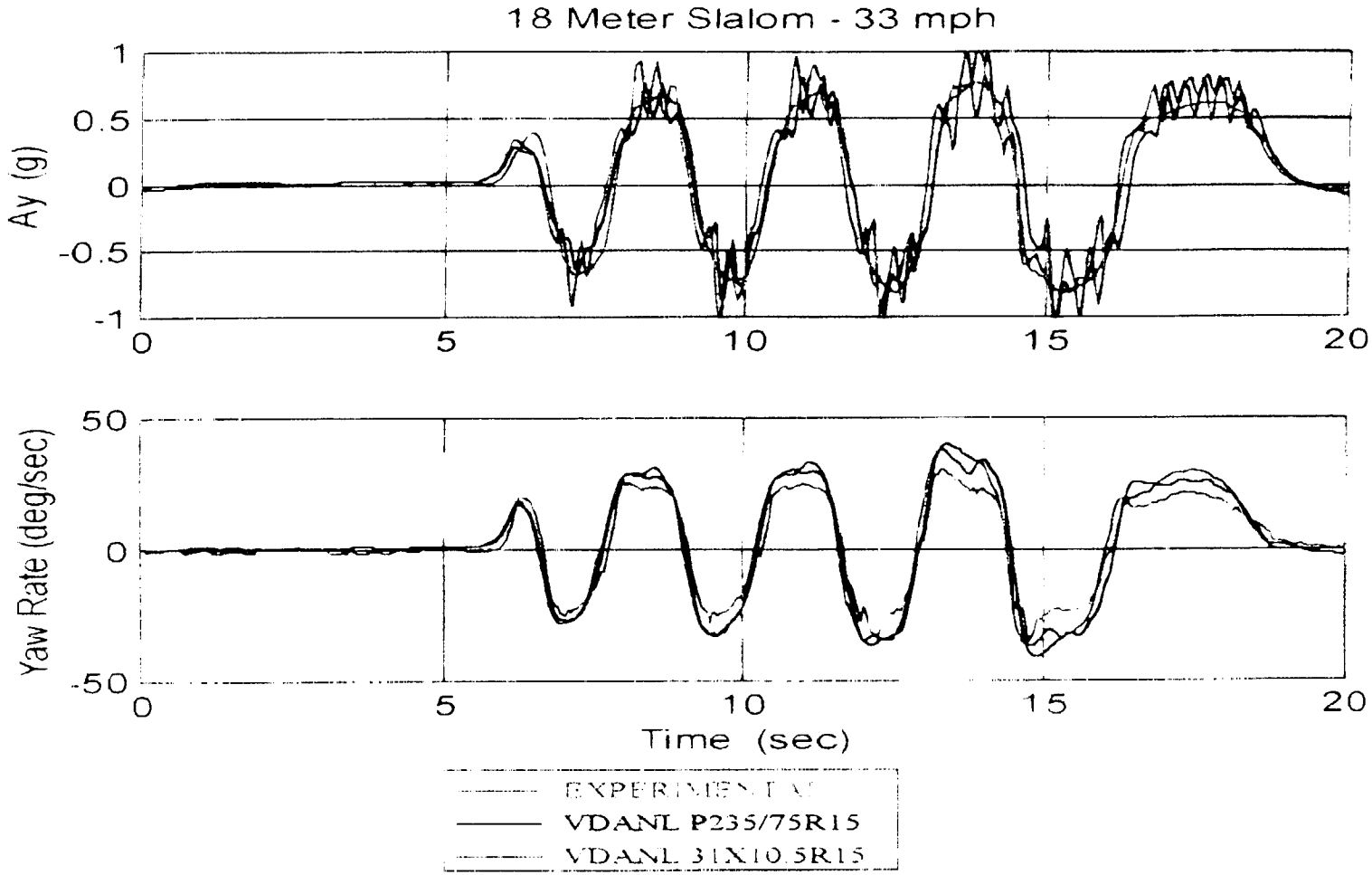
Figure 5 - VDANL Understeer Gradient Comparison - 83 km/h

Evaluation of VDANL Validity by Heydinger

- 1996 Isuzu Trooper 4x4
- "Based on reviews of past evaluations and the thorough evaluation done using measured results from the 1996 Isuzu Trooper, VDANL was found to be not capable of predicting exactly the discrete events at the limits of vehicle responses."
- VDANL was found to "…over predict yaw response…" and "…under predicts Trooper dynamic understeer…"
- The VDANL predictions "…are not in good agreement with the actual, measured responses of the 1996 Isuzu Trooper"
- "The VDANL simulation suspension model, particularly the modeling of the bump stops and the lack of modeling nonlinear suspension characteristics, is inadequate for correctly modeling the suspension behavior of the 1996 Isuzu Trooper at high lateral acceleration levels."

Evaluation of VDANL Validity by Heydinger

1996 Isuzu Trooper 4x4



Evaluation of VDANL Validity by NHTSA

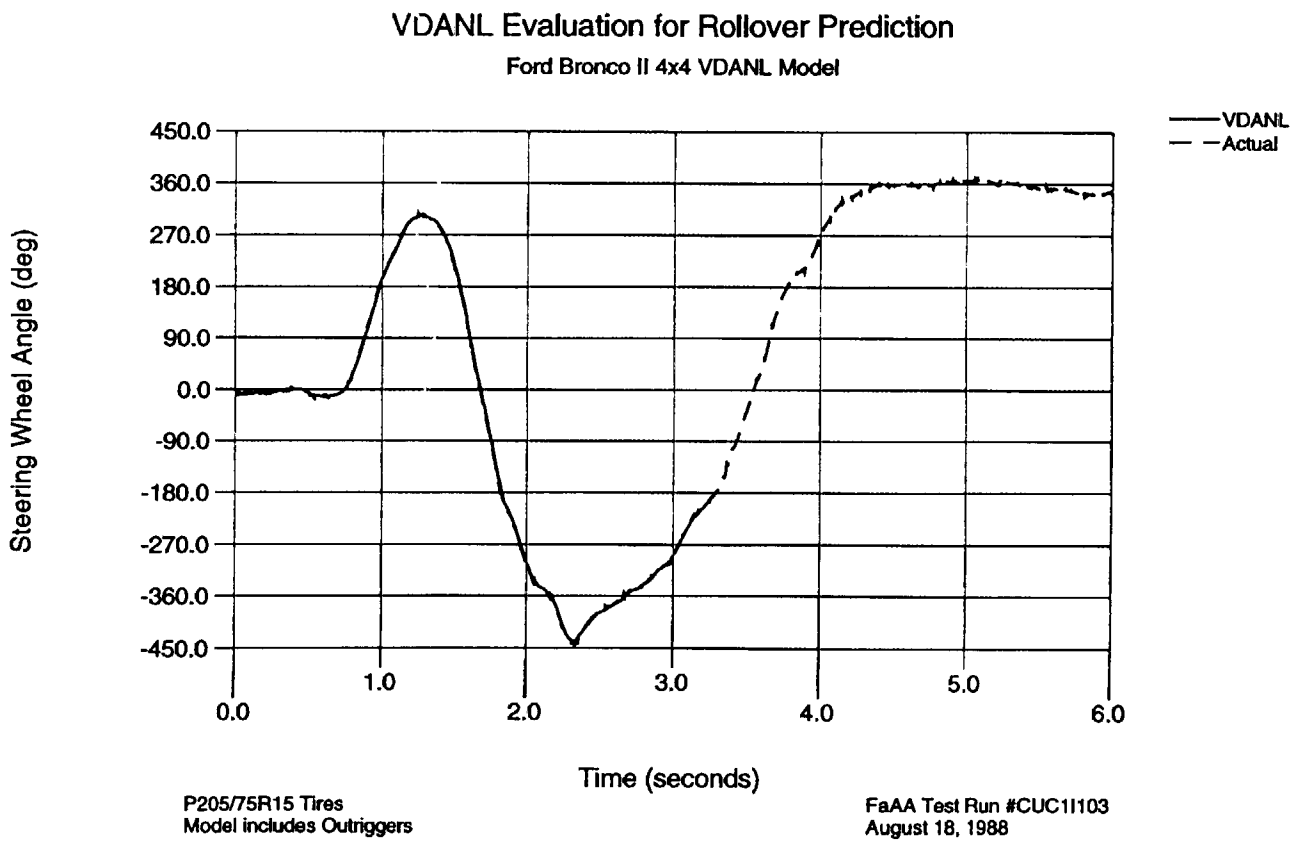
- "Although the VDANL simulation program provides valid predictions of vehicle behavior during most vehicle operations, a shortcoming in its suspension sub-program undermines its ability to predict the precise performance of the subject vehicles at certain limit conditions, such as those experienced during the CU short course maneuver and other severe driving maneuvers that cause the vehicles' bump stops to be engaged."
- "Although the computer simulation submitted by CU indicated that the subject vehicles would switch from understeer to oversteer at high lateral acceleration levels, testing of the subject vehicles by NHTSA and Isuzu indicates that the vehicles understeer throughout a range of lateral accelerations up to nearly 0.8 g's."

Evaluation of VDANL Validity by Carr Engineering, Inc.

- Ford Bronco II 4x4 and Chevrolet S-10 Blazer 4x4 in "modified" Consumers Union lane change runs
- Toyota 4Runner 4x2 in a high speed turn test
- Isuzu Trooper 4x4 simulated in various Consumers Union "short course" maneuvers with different versions of VDANL

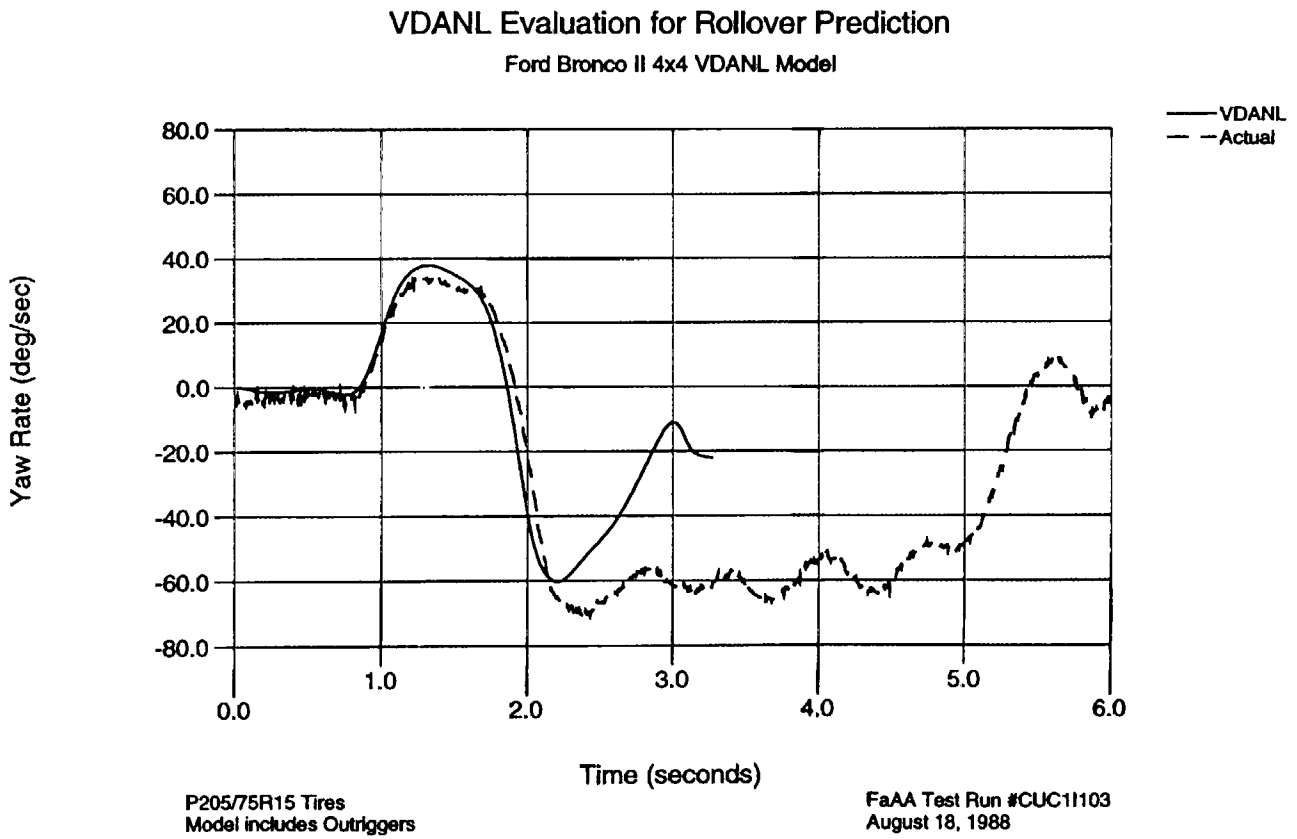
Evaluation of VDANL Validity by Carr Engineering, Inc.

Ford Bronco II 4x4 in modified CU course



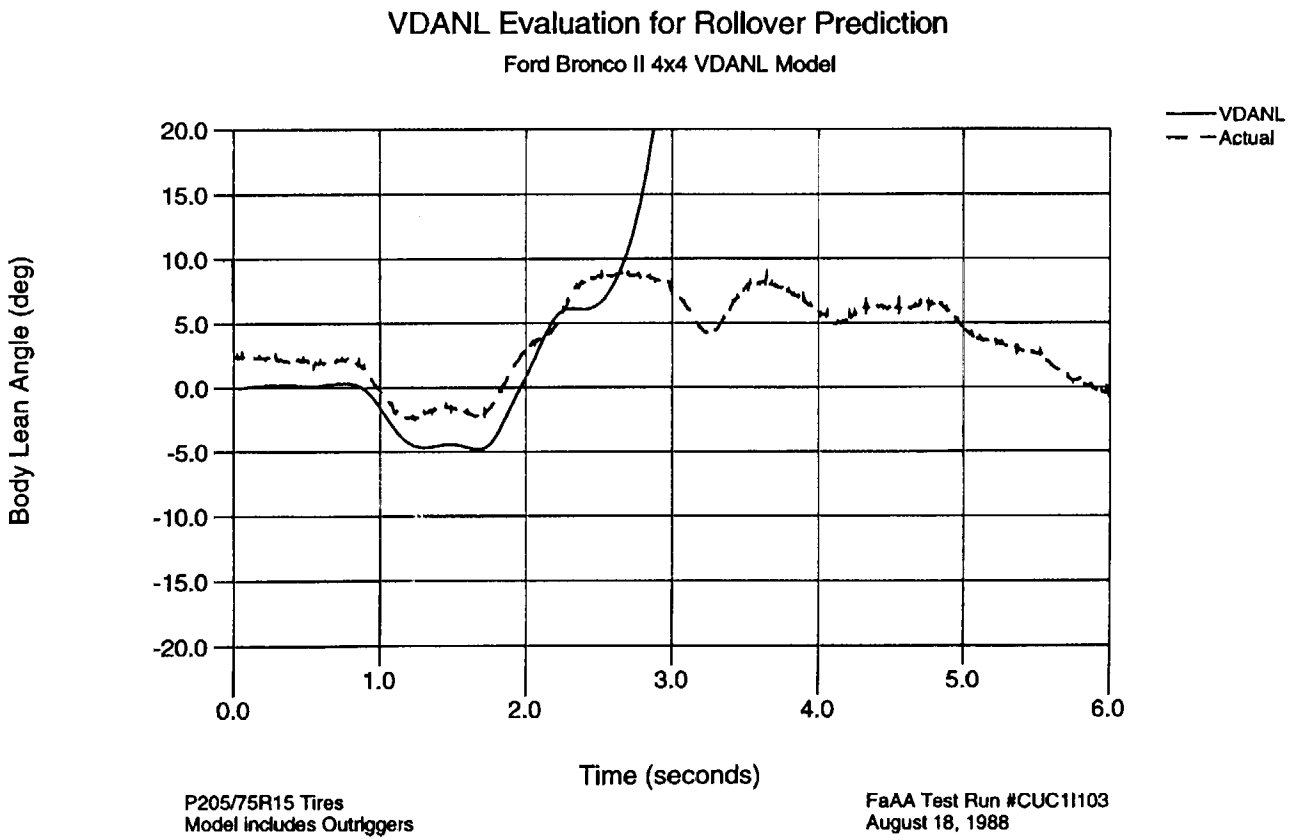
Evaluation of VDANL Validity by Carr Engineering, Inc.

Ford Bronco II 4x4 in modified CU course



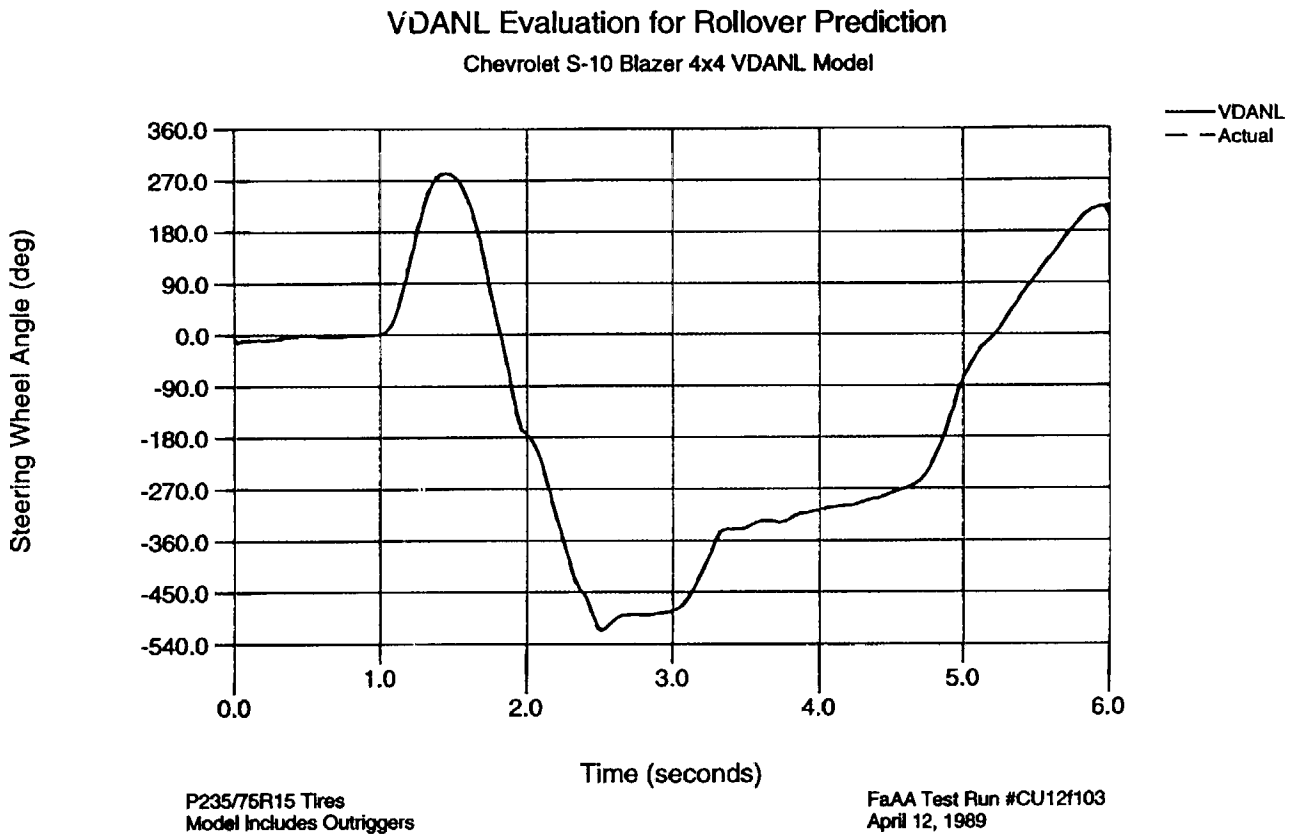
Evaluation of VDANL Validity by Carr Engineering, Inc.

Ford Bronco II 4x4 in modified CU course



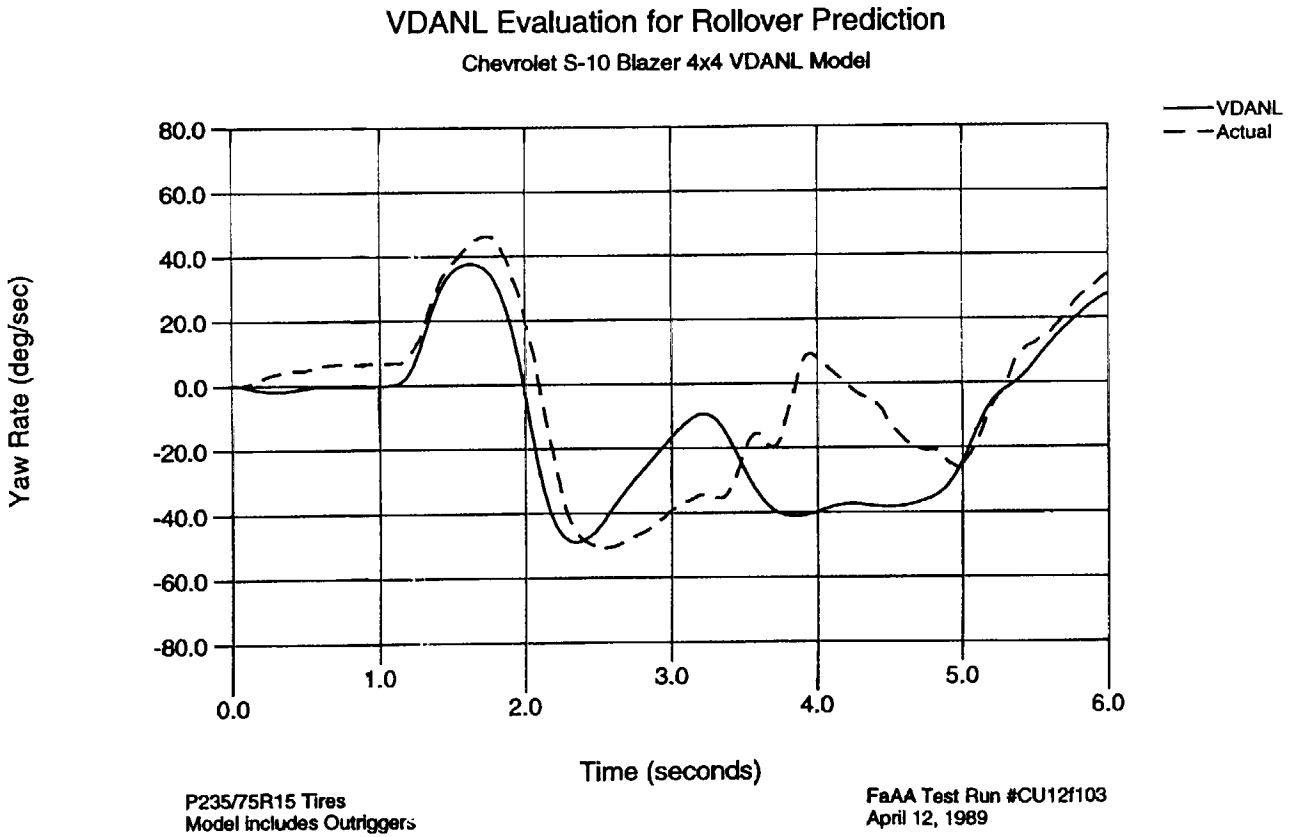
Evaluation of VDANL Validity by Carr Engineering, Inc.

Chevrolet S-10 Blazer 4x4 in modified CU course



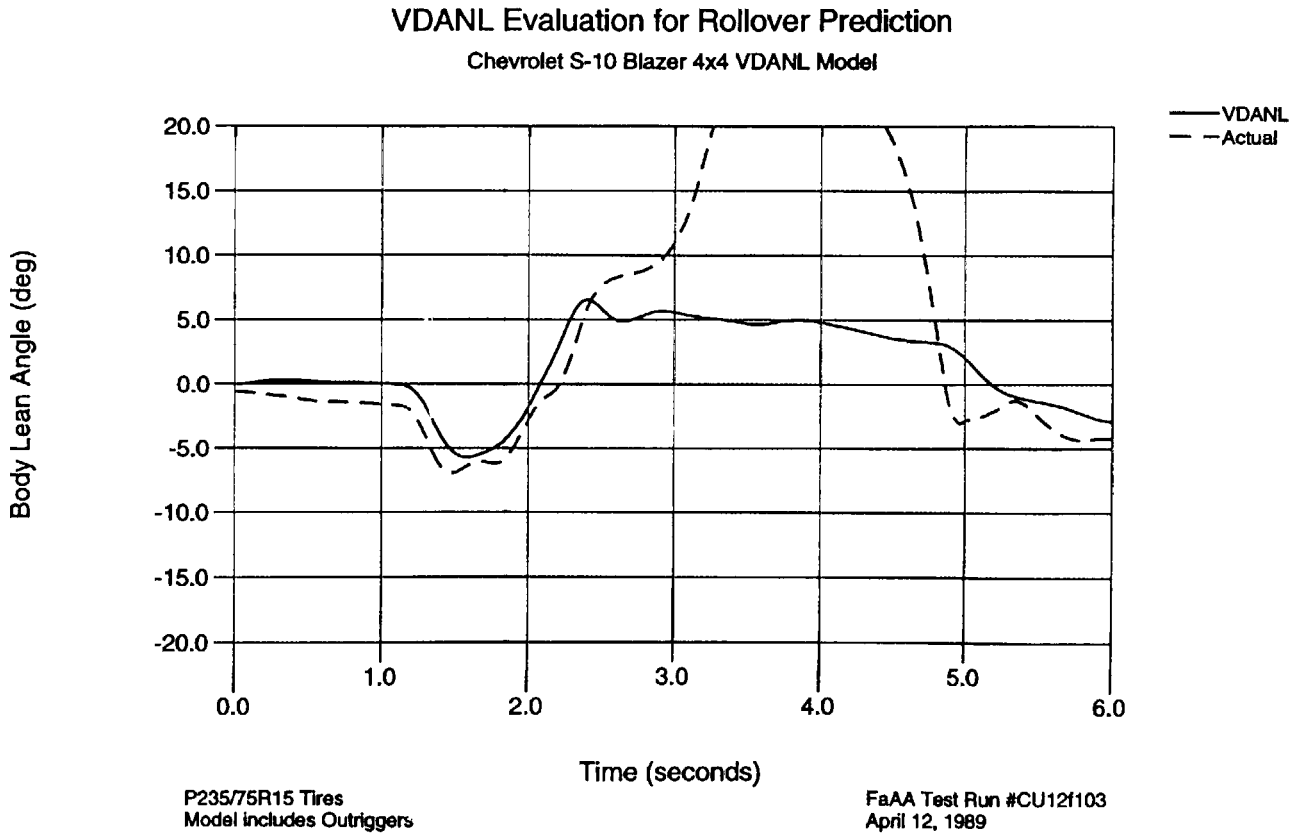
Evaluation of VDANL Validity by Carr Engineering, Inc.

Chevrolet S-10 Blazer 4x4 in modified CU course



Evaluation of VDANL Validity by Carr Engineering, Inc.

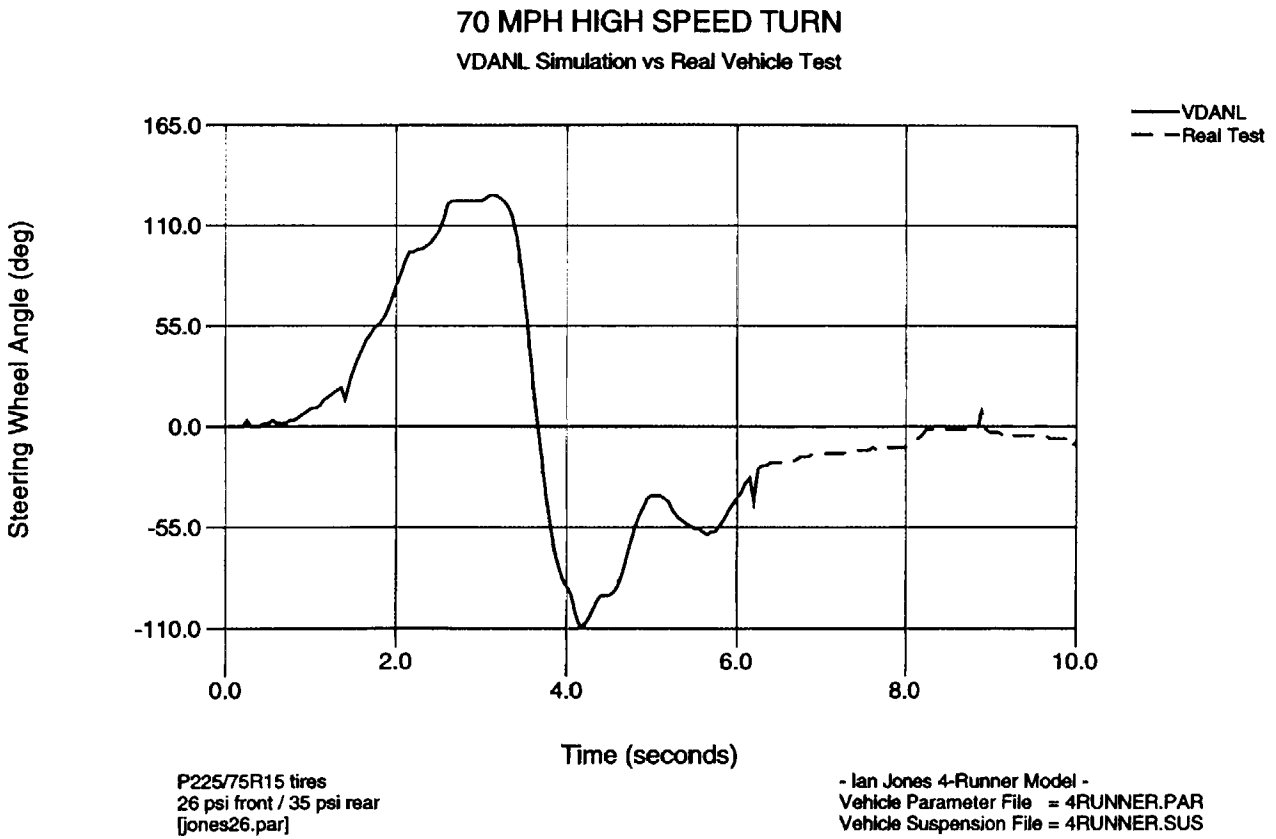
Chevrolet S-10 Blazer 4x4 in modified CU course



Show Bronco II and S-10 Blazer VDANL Evaluation of Validity Video

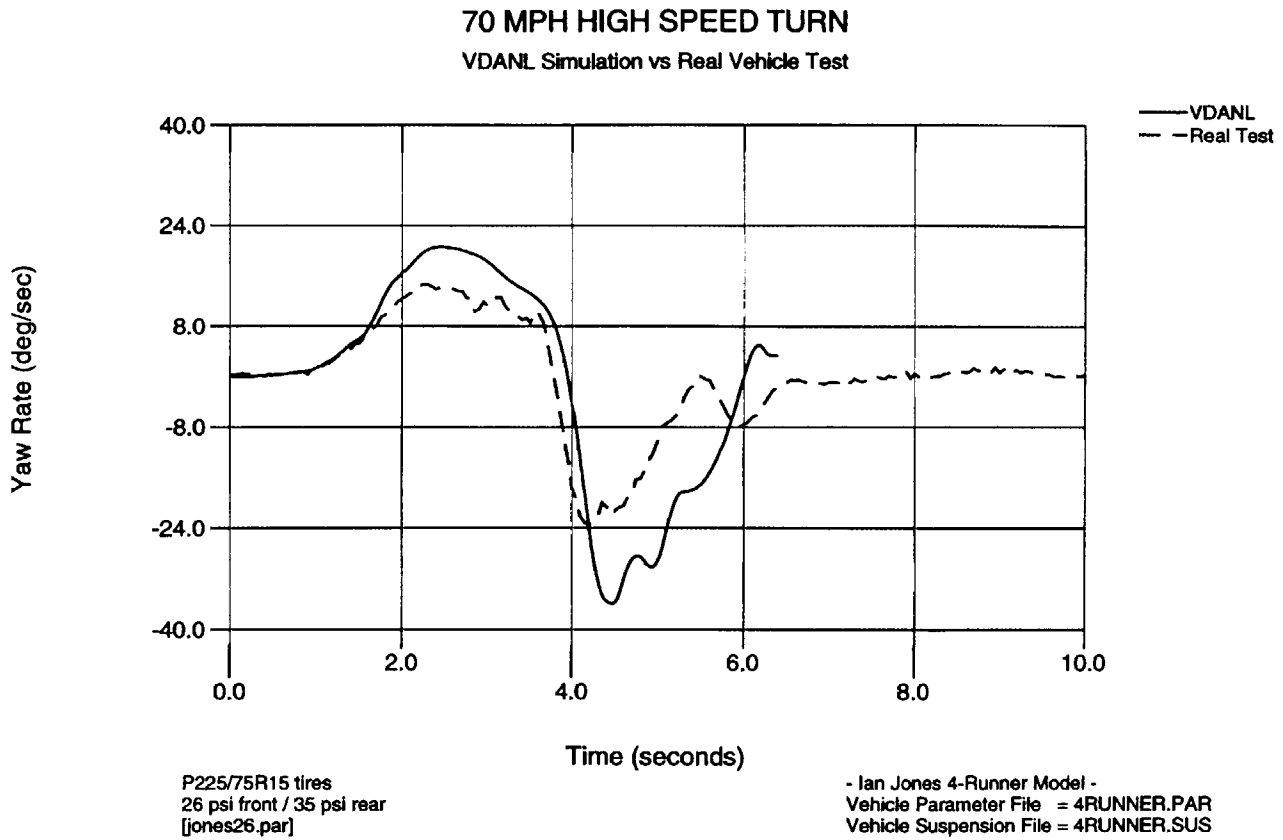
Evaluation of VDANL Validity by Carr Engineering, Inc.

1994 Toyota 4Runner 4x2



Evaluation of VDANL Validity by Carr Engineering, Inc.

1994 Toyota 4Runner 4x2



Show Toyota 4Runner 4x2 VDANL
Evaluation of Validity Video

Evaluation of VDANL Validity by Carr Engineering, Inc.

1996 Isuzu Trooper 4x4 in CU "short course" maneuvers

	Actual	VDANL Version			
	Test	3.54	4.18a	5.00sig	5.043
Run 7 @ 37.5 mph	No	2wl	No	2wl	Roll
Run 8 @ 37.5 mph	No	2wl	No	2wl	Roll
Run 9 @ 37.1 mph	No	2wl	No	2wl	Roll
Run 13 @ 36.2 mph	No	2wl	2wl	Roll	Roll
Run 16 @ 36.6 mph	No	Roll	2wl	2wl	Roll
Run 17 @ 35.9 mph	No	2wl	2wl	2wl	Roll
Run 18 @ 36.5 mph	No	2wl	2wl	2wl	Roll
Run 19 @ 36.3 mph	No	2wl	2wl	2wl	Roll

Legend: NO = no 2 wheel lift or overturn 2wl = 2 wheel lift Roll = overturn

Evaluation of VDANL Validity by Carr Engineering, Inc.

- VDANL is too simplistic to faithfully represent a real vehicle in a real world maneuver, especially at the limits of tire traction
- VDANL cannot predict yaw or lateral dynamics due to its inherent vehicle model and tire model problems
- VDANL cannot predict whether a vehicle will overturn or not with any degree of accuracy
- Different versions of VDANL predict different results with identical input parameters

QUESTION:

Do the NHTSA VDANL Simulations of a Fifteen-Passenger Van Predict Actual Vehicle Performance?

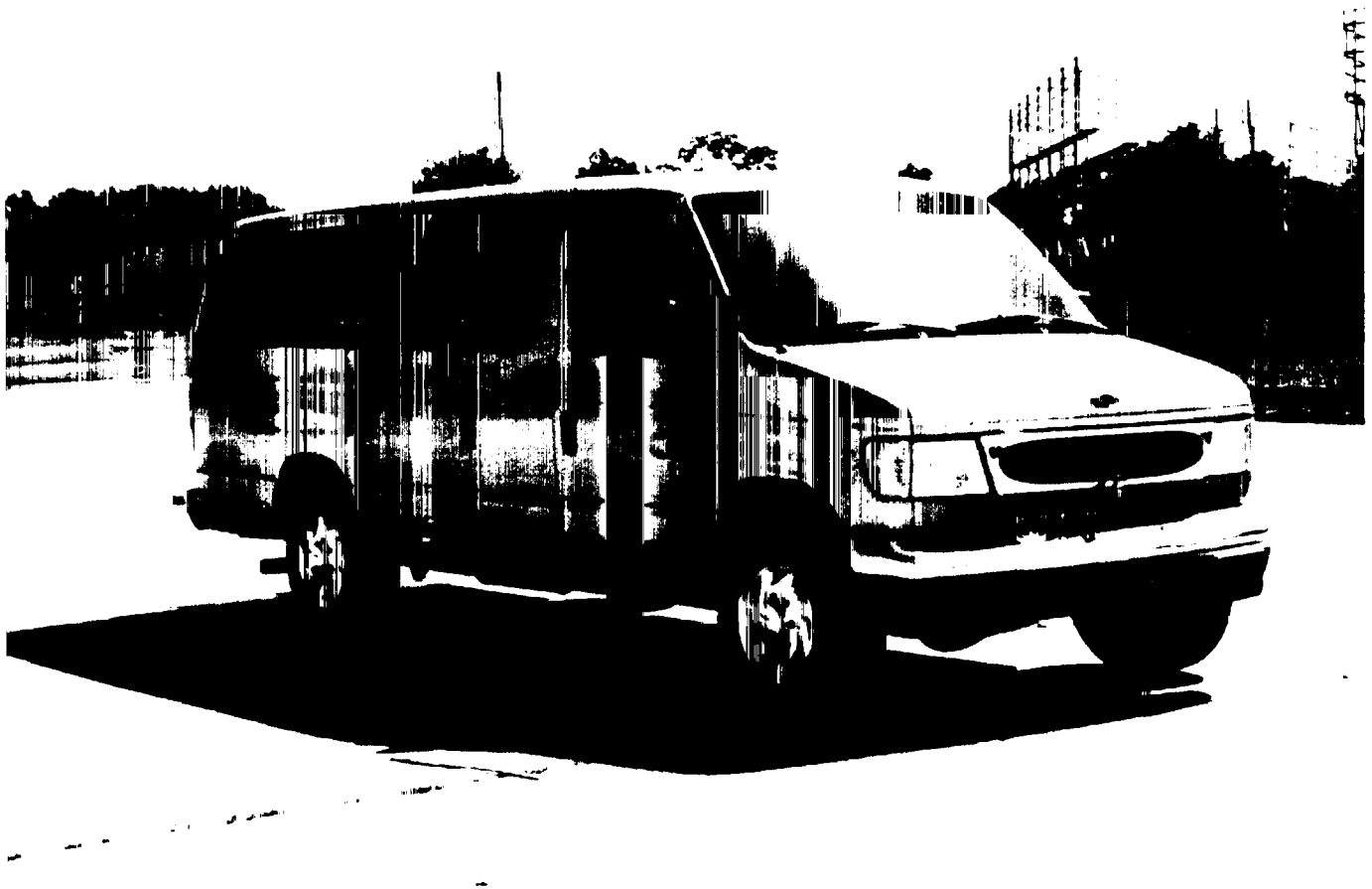
ANSWER:

NO

To Answer This Questions, Ford Ran Extensive Tests on a 2000 Ford E-350 Fifteen-Passenger Van. Tests Were Performed at Curb Plus and at GVW Loading. Some Tests Were Performed With a Steering Controller.

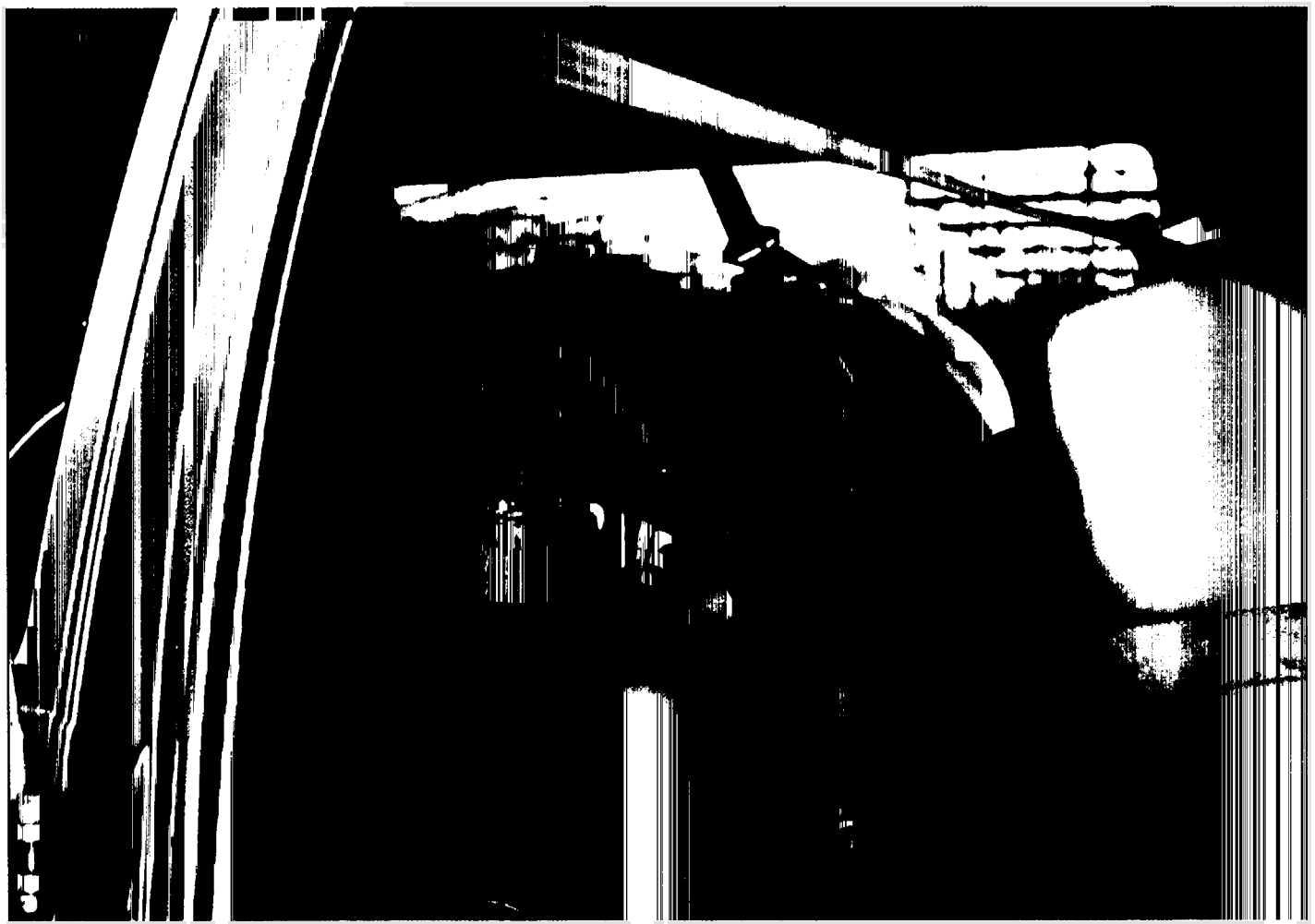
2000 Ford E-350 Fifteen-Passenger Van

Goodyear Wrangler HT LT245/75R16E Tires



Ford Van Instrumented With Steering Controller

Ford Van Loaded With Water Dummies



What Simulated Maneuvers Did NHTSA Rely on in It's Research Note Study?

- 30 mph slowly increasing steer maneuver
- 30 mph reverse steer maneuver (180 degrees / 180 degrees at 360 degrees/second)

Note: Both maneuvers run at curb + driver and gross vehicle weight rating (fully loaded)

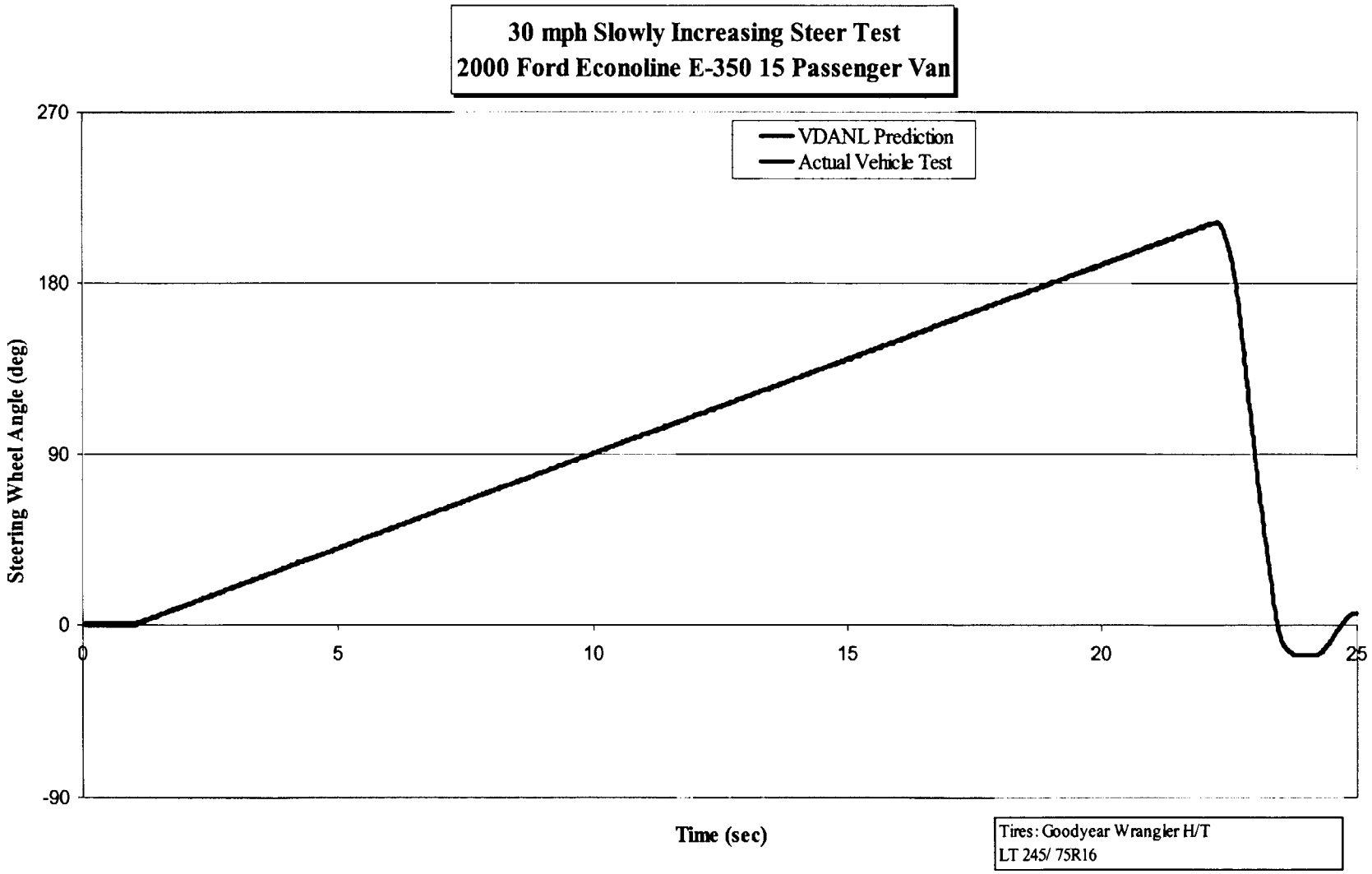
NHTSA's Reported Results From the VDANL Simulation of a 30 mph Slowly Increasing Steer Maneuver

- The fifteen-passenger van simulation rolled over at 0.55 g's
- "This maneuver is useful for determining understeer and load transfer characteristics of a vehicle"
- "At GVW the simulated vehicle exhibits a transition towards oversteer above 0.4 g. lateral acceleration, while the LLW vehicle exhibits limit understeer."
- "This sort of transition is known to cause safety problems, particularly for drivers who normally only drive smaller passenger vehicles and who are therefore unfamiliar with a loaded fifteen-passenger van's responsiveness and limits."

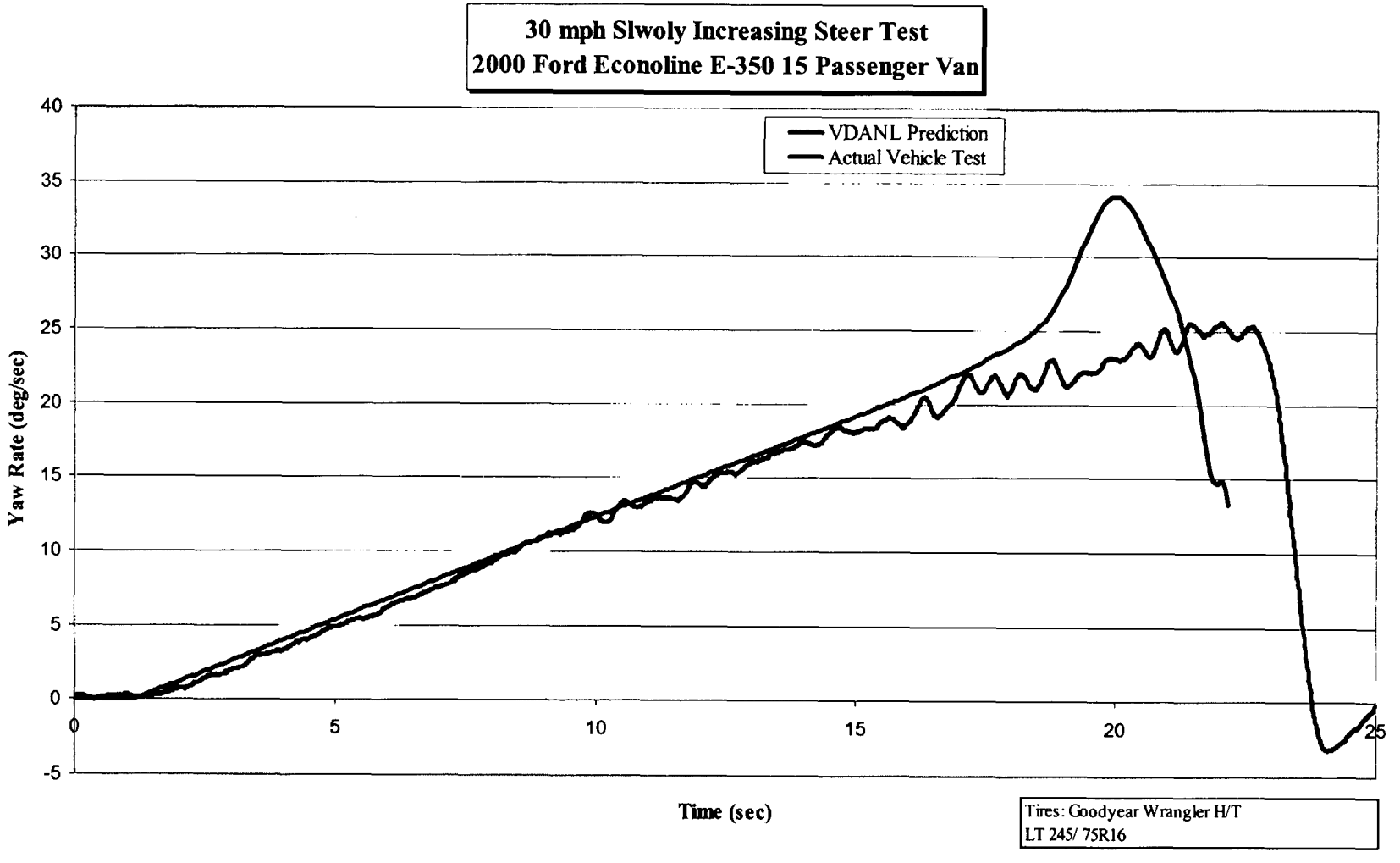
Ford's Conclusions From the 30 mph Slowly Increasing Steer Maneuver on an Actual Vehicle

- The Ford fifteen-passenger van will not rollover or lift tires at 0.55 g's or at any other lateral acceleration level in this test
- At GVW the simulated vehicle does not ***oversteer***, even at the tire traction limits, the fifteen passenger van is an understeer vehicle
- There was no transition and therefore no "… safety problems, particularly for drivers who normally only drive smaller passenger vehicles…"

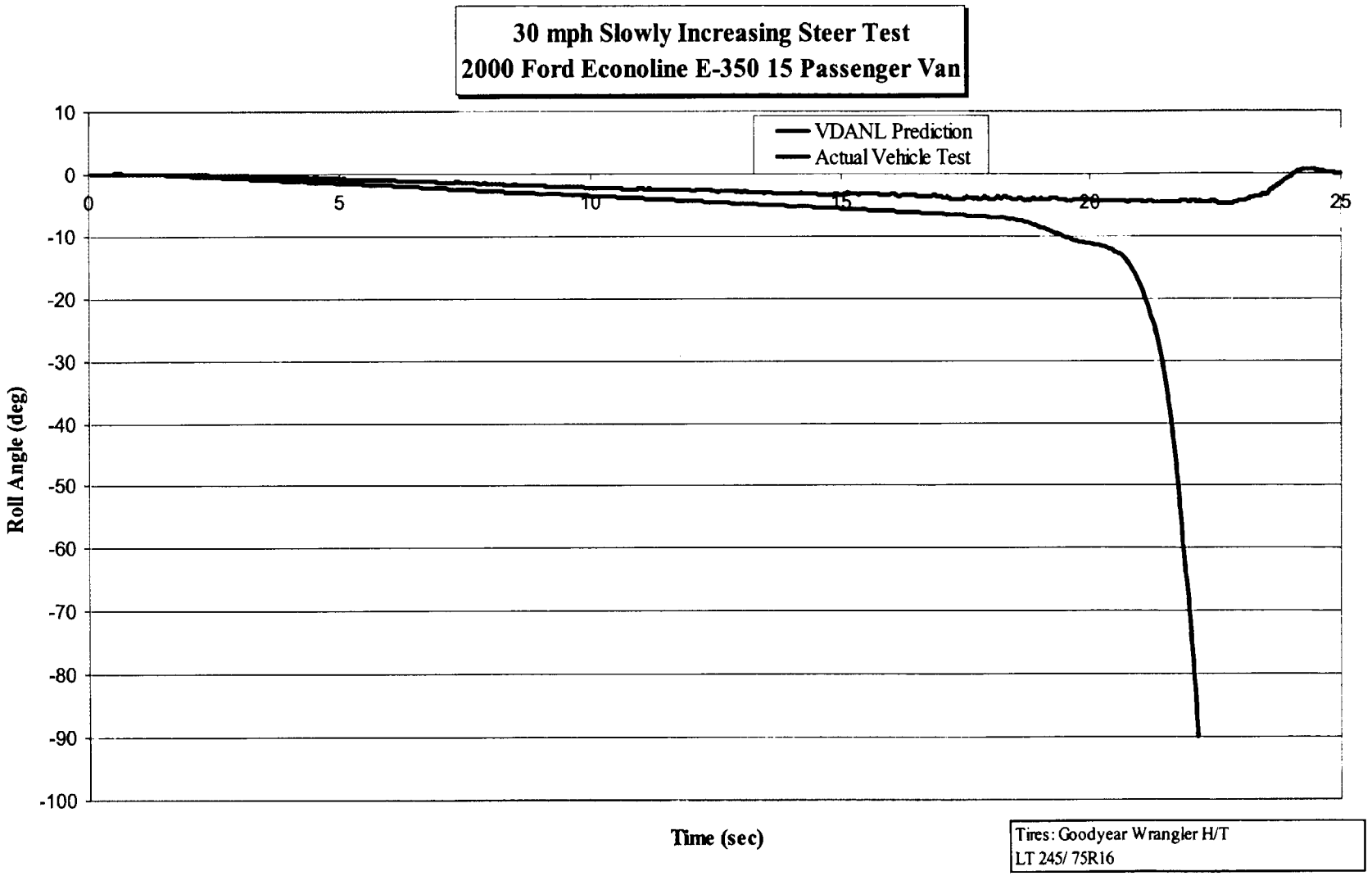
Comparison of Steering Input



Comparison of Yaw Response

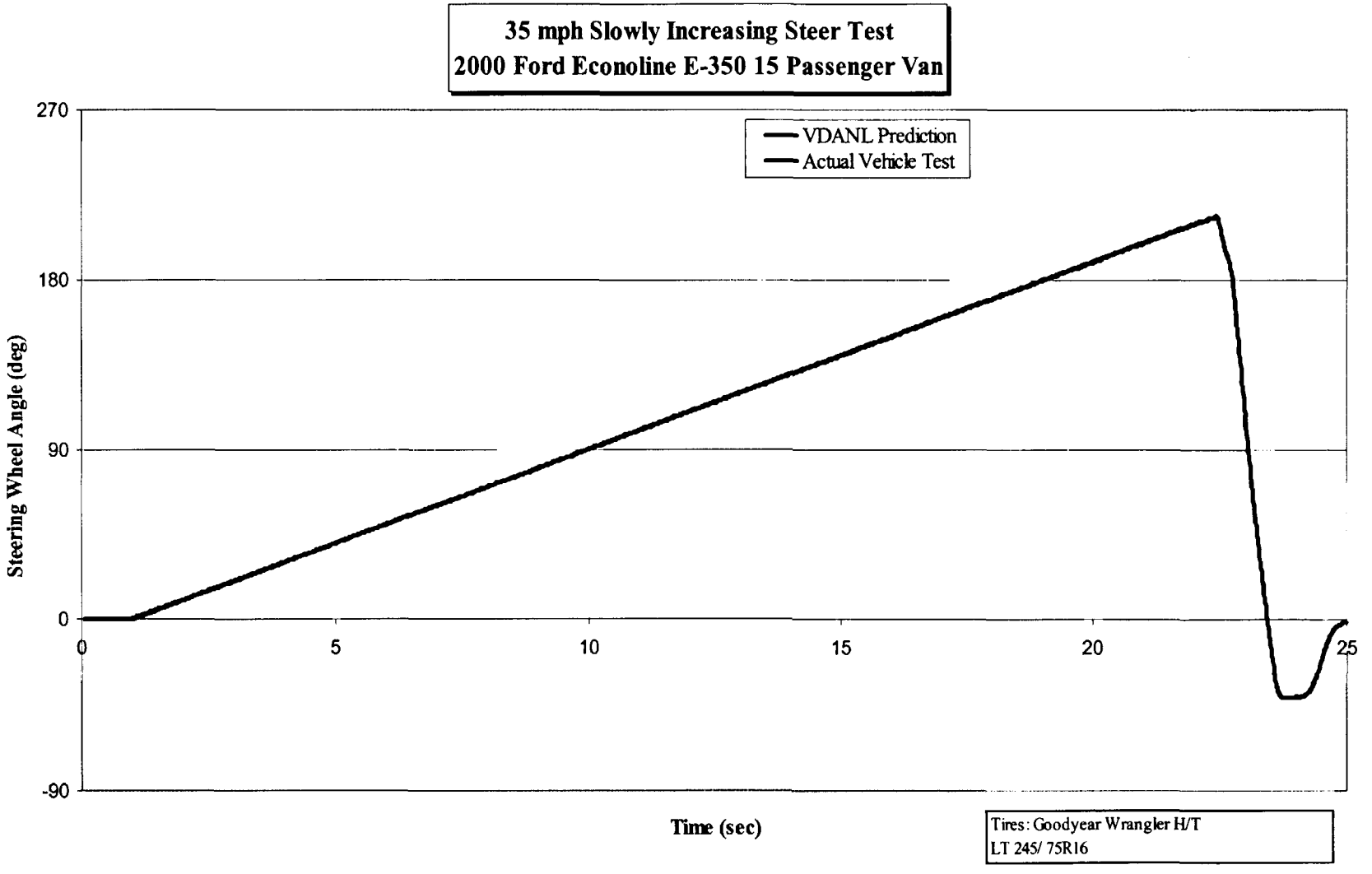


Comparison of Roll Response

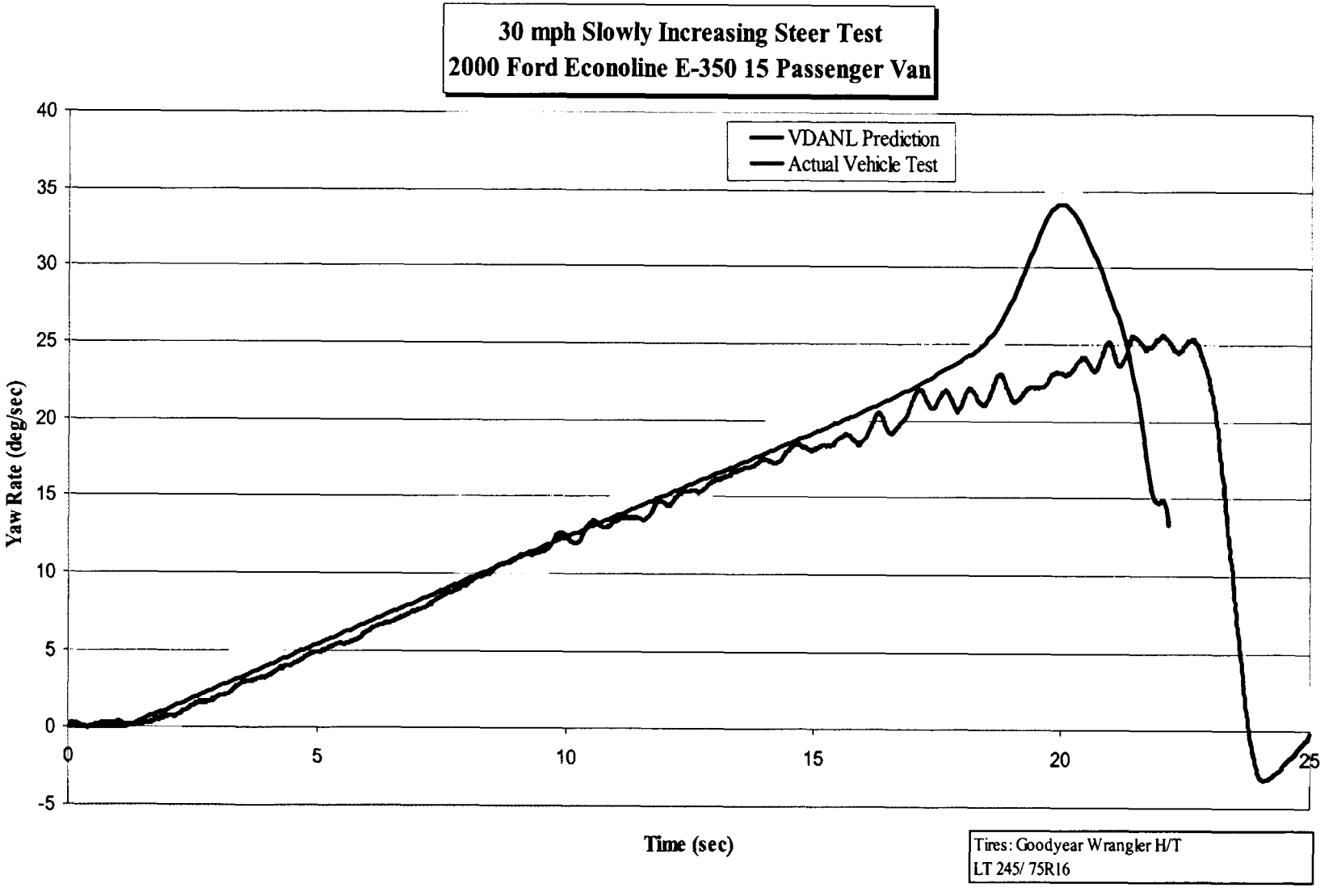


Ford Repeated This Test Procedure at 35 Miles Per Hour and Found Similar Discrepancies Between Actual Vehicle Performance and VDANL Predictions

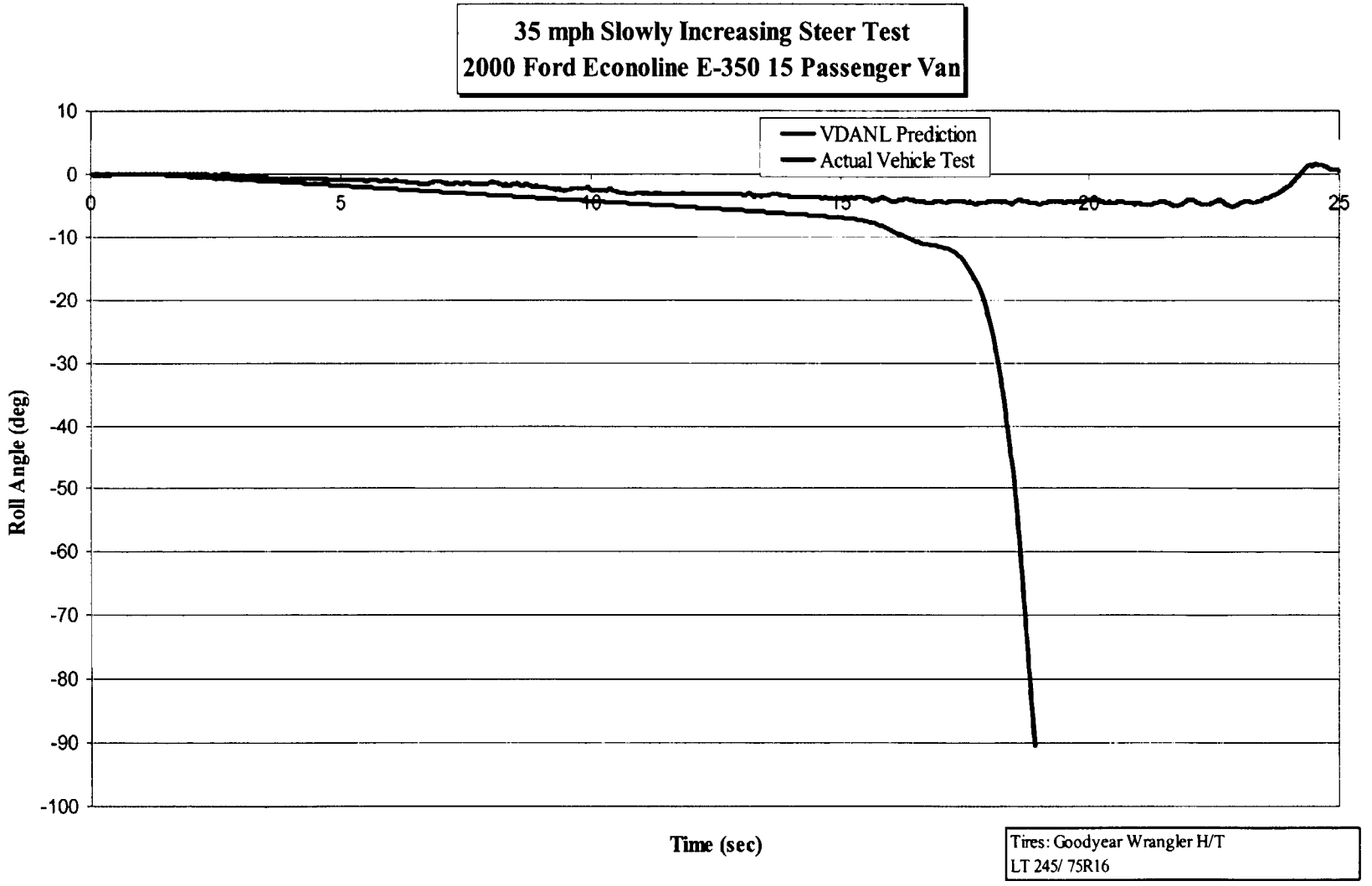
Comparison of Steering Input



Comparison of Yaw Response



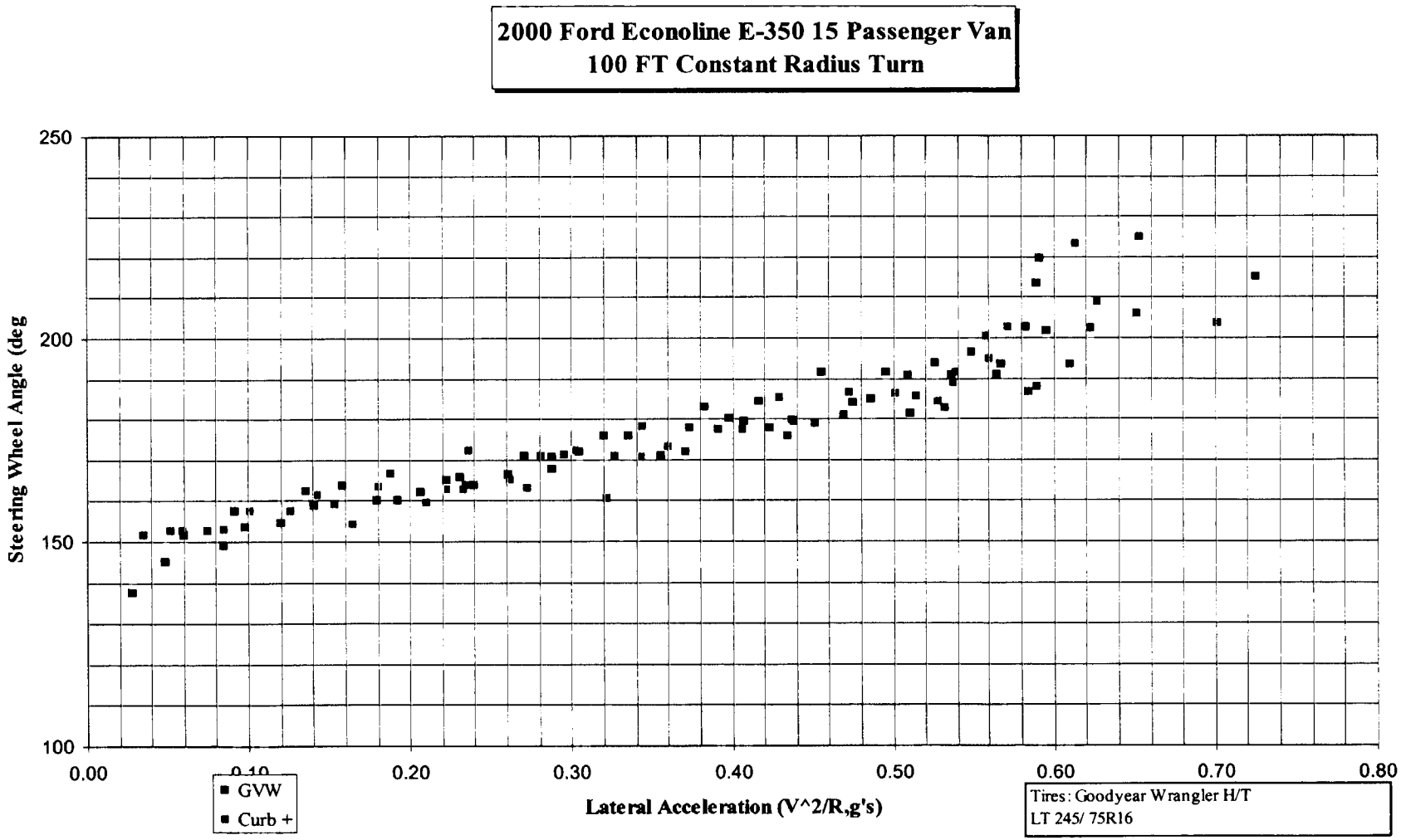
Comparison of Roll Response



Ford Also Performed Constant Radius Understeer Tests on a Fifteen-Passenger Van Pursuant to SAE Recommended Practice J266

- 100 foot radius circle
- High traction brushed concrete surface
- Tests performed at curb plus and GVW loading

Contrary to the VDANL Prediction, The Actual Ford Fifteen-Passenger Van Has Similar Understeer Loaded and Unloaded

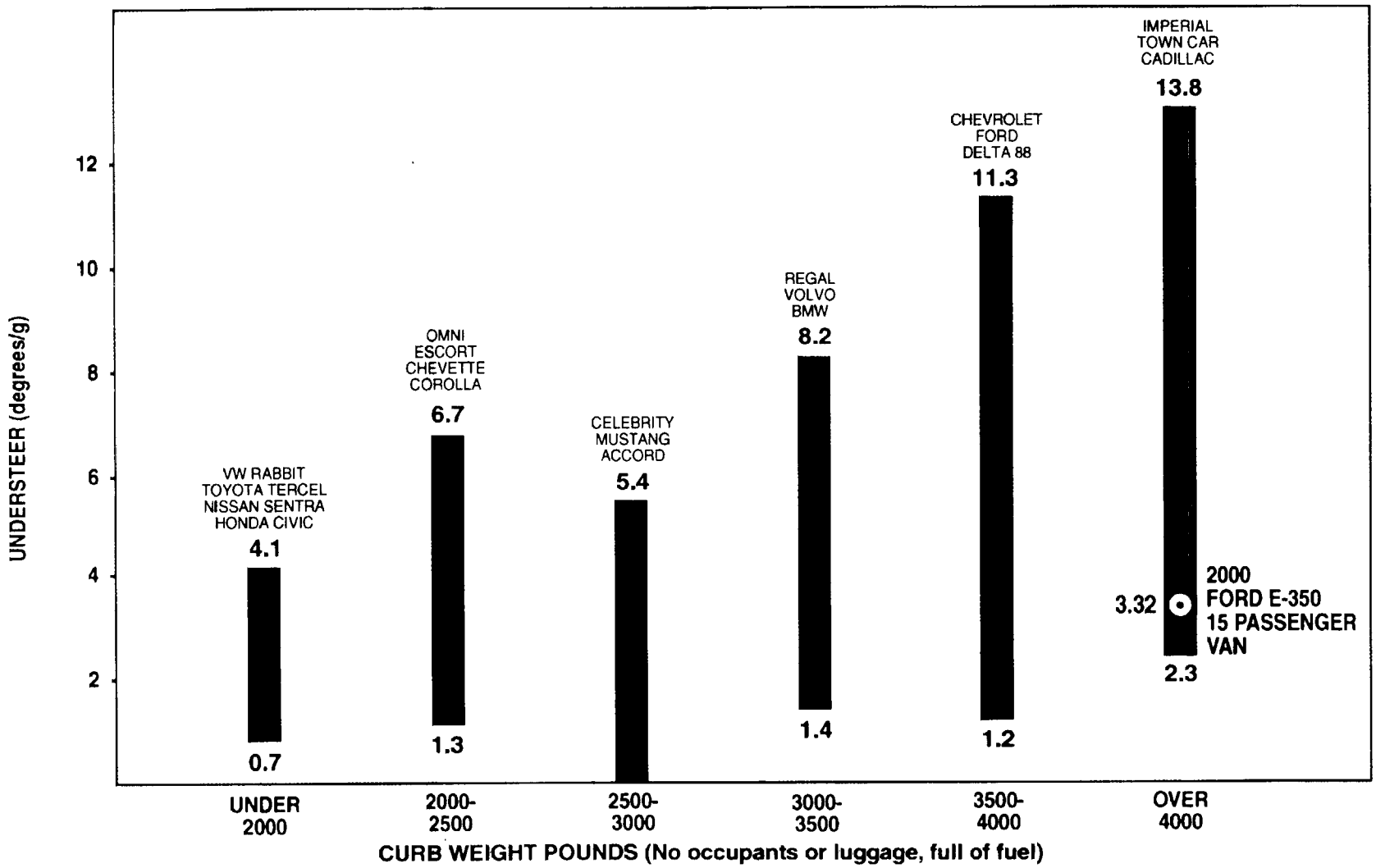


Ford Also Performed an Understeer and Steering Sensitivity Procedure Adopted by General Motors to Determine Understeer and Steering Sensitivity of a Fifteen-Passenger Van Loaded to GVW

- 62 mph (100 kph) step steer test
- Procedure and comparison vehicle data in "Typical Vehicle Parameters," Riede, Leffert & Cobb, SAE Paper 840561

This Testing Confirmed That the Ford E-350 Fifteen-Passenger Van Has Understeer When Fully Loaded to GVW and That It's Magnitude is Similar to That of Other Vehicle Types in an Unloaded Condition

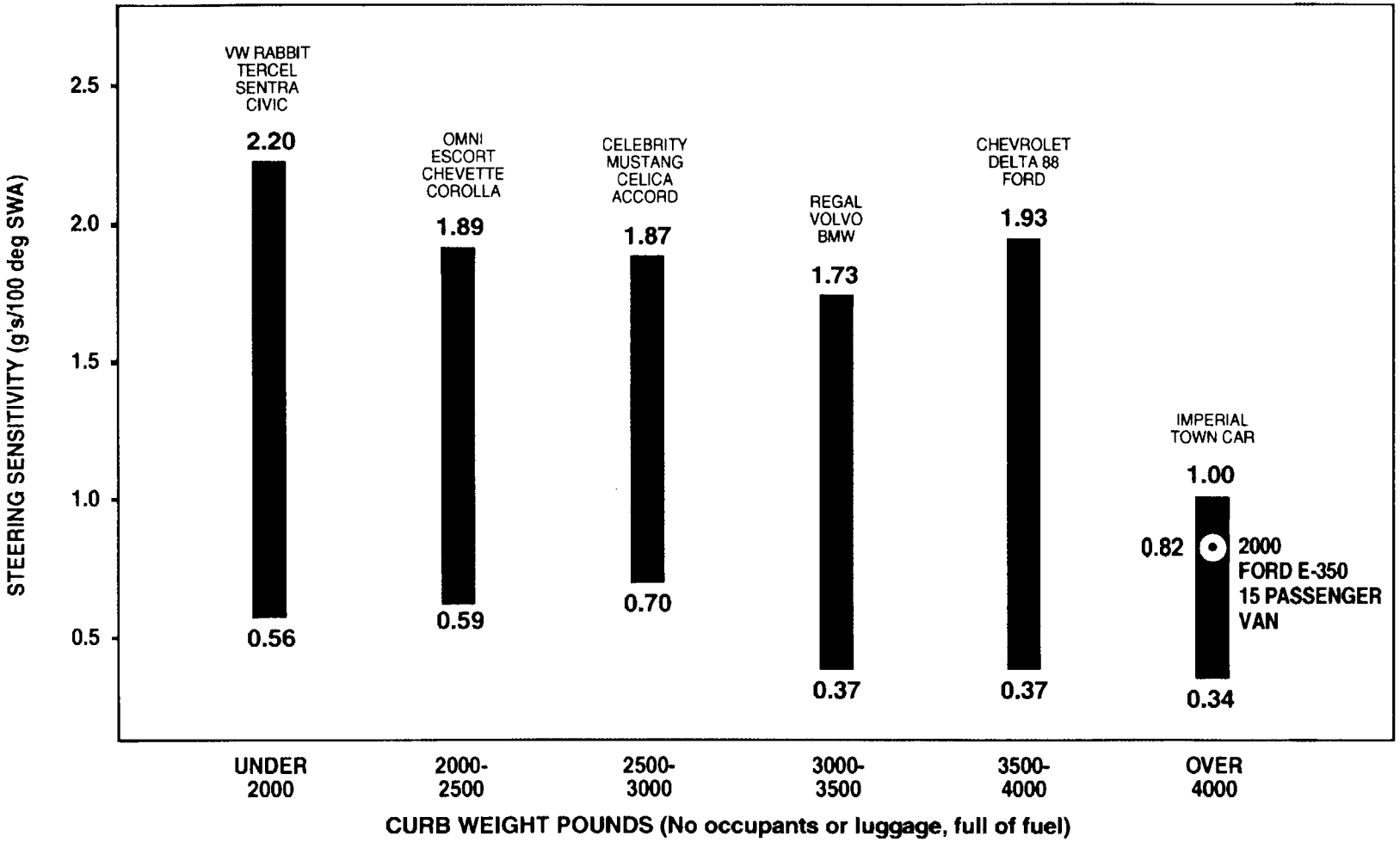
UNDERSTEER COMPARISON



SOURCES: *1. "TYPICAL VEHICLE PARAMETERS," RIEDE, LEFFERT & COBB. SAE PAPER 840561,02/84*
2. CARR ENGINEERING STEP STEER TEST, 2000 FORD E-350 15 PASSENGER VAN (AT GVW)

This Testing Also Confirmed That the Steering Sensitivity or Steering Gain of The Ford E-350 Fifteen-Passenger Van is Not Odd or Unusual and Compares Well to Other Vehicle Types in an Unloaded Condition

STEERING SENSITIVITY COMPARISON



SOURCES: *1. "TYPICAL VEHICLE PARAMETERS," RIEDE, LEFFERT & COBB. SAE PAPER 840561,02/84*
2. CARR ENGINEERING STEP STEER TEST, 2000 FORD E-350 15 PASSENGER VAN (AT GVW)

Ford's Conclusions From the SAE J266 and General Motors Understeer Tests

- At both the curb and GVW loading conditions, the fifteen-passenger van has linear range understeer
- At both the curb and GVW loading conditions, the vehicle remains understeering up through the limits of tire traction
- At no time did the vehicle lift its inside tires or rollover
- The fifteen passenger van has appropriate understeer and steering sensitivity, even when loaded to GVW

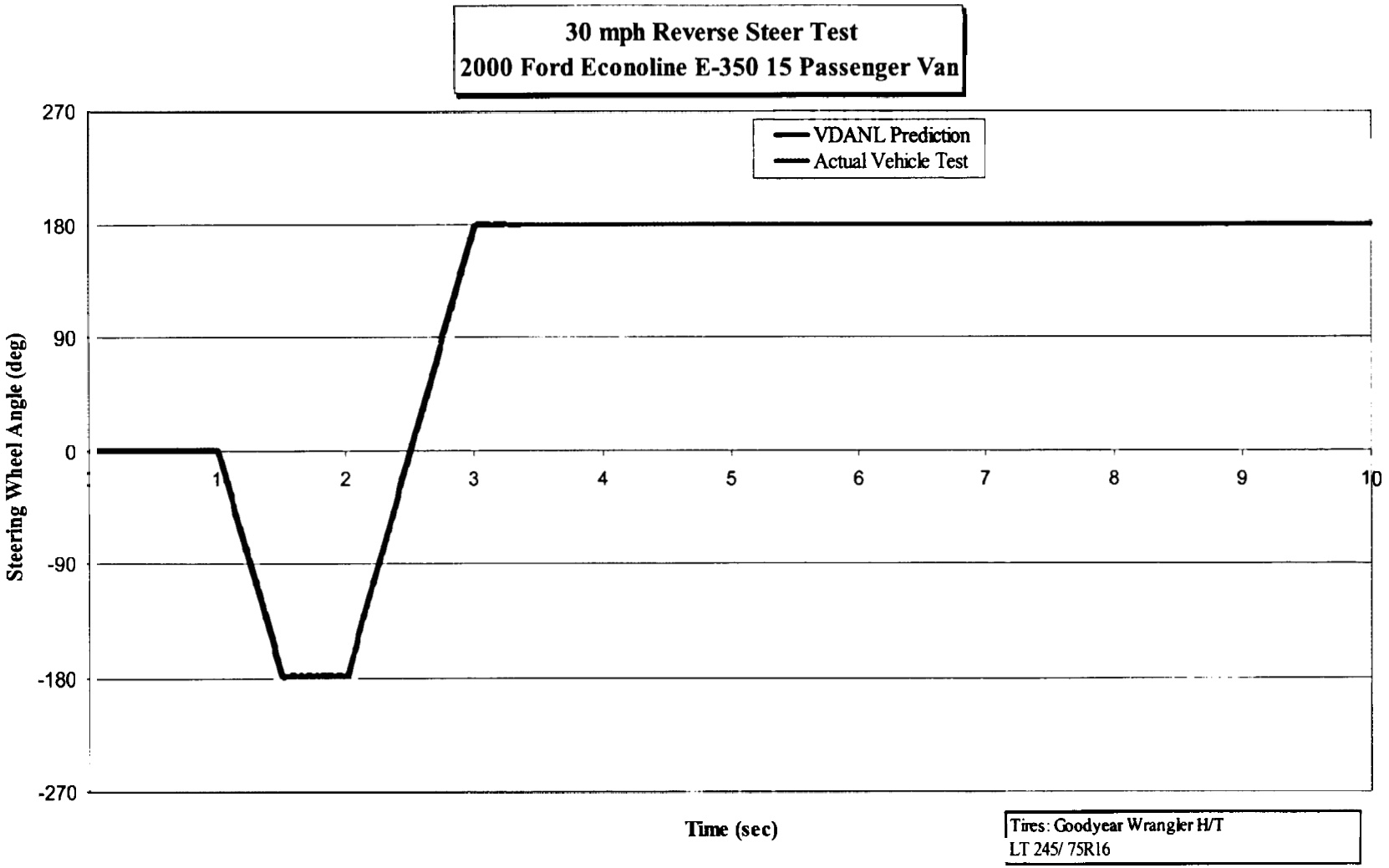
NHTSA Reported Results From the VDANL Simulation of a 30 mph Reverse Steer Maneuver

- This maneuver will overturn a fifteen-passenger van
- "The simulated LLW vehicle remains stable throughout this maneuver while the GVW vehicle rolls over."
- "These examples show that the simulated GVW fifteen-passenger van exhibits both lateral and roll instabilities under extreme maneuvers."
- "The roll instability results from the facts that the GVW vehicle spins out and that the center of gravity is higher."

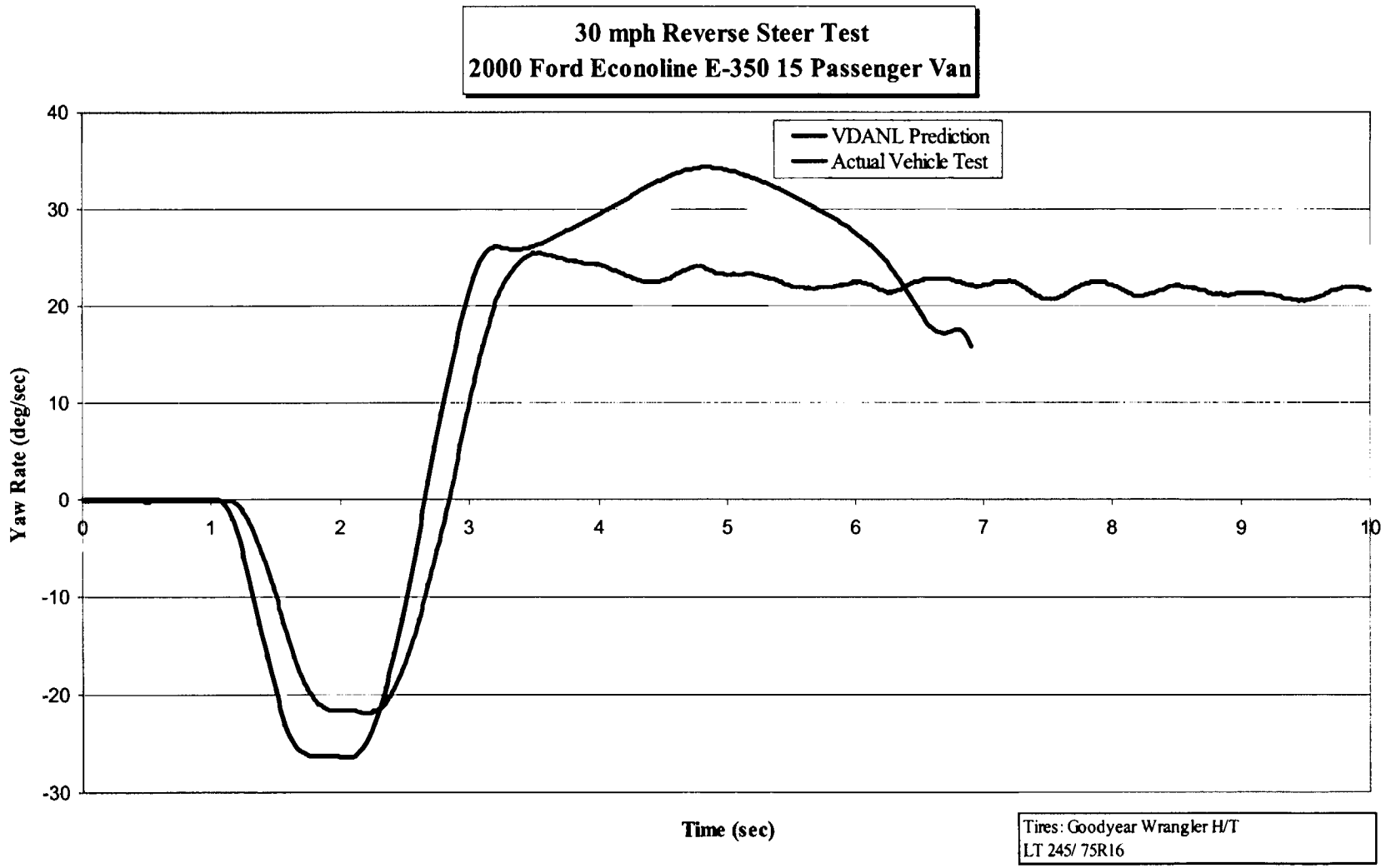
Ford's Conclusions From the 30 mph Reverse Steer Maneuver on an Actual Vehicle

- This maneuver will ***Not*** overturn a fifteen-passenger van
- The actual vehicle when loaded to GVW remains stable throughout this maneuver and does not demonstrate "…lateral and roll instabilities under extreme maneuvers"
- The actual fifteen-passenger van when loaded to GVW did not spin out or lift any tires free from the ground during the reverse steer maneuver

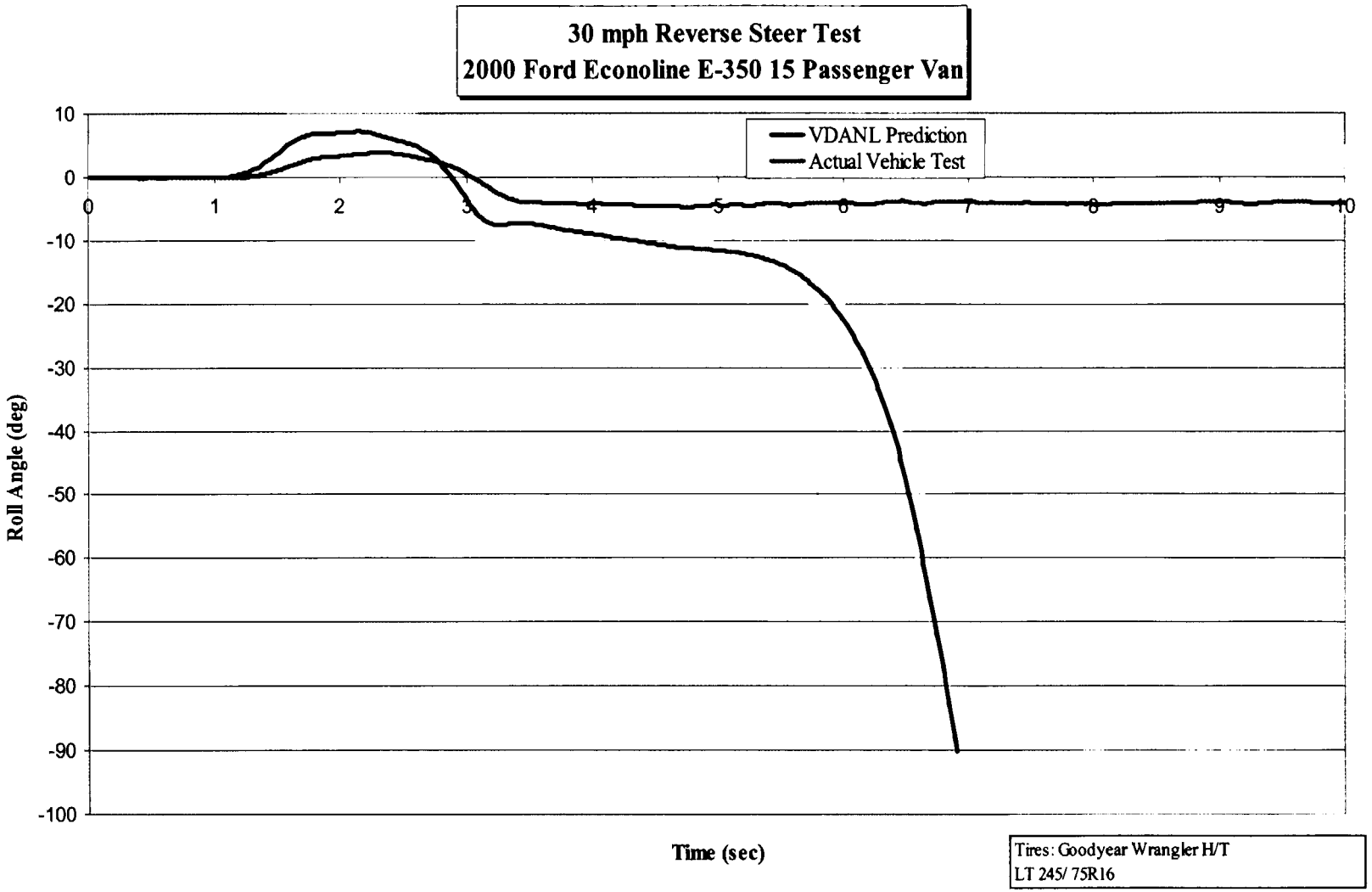
Comparison of Steering Input



Comparison of Yaw Response



Comparison of Roll Response



To Further Study VDANL's Ability to Predict the Real World Performance of a Fifteen-Passenger Van, Ford Ran Several Step Steer Maneuvers on an Actual Vehicle With a Steering Controller

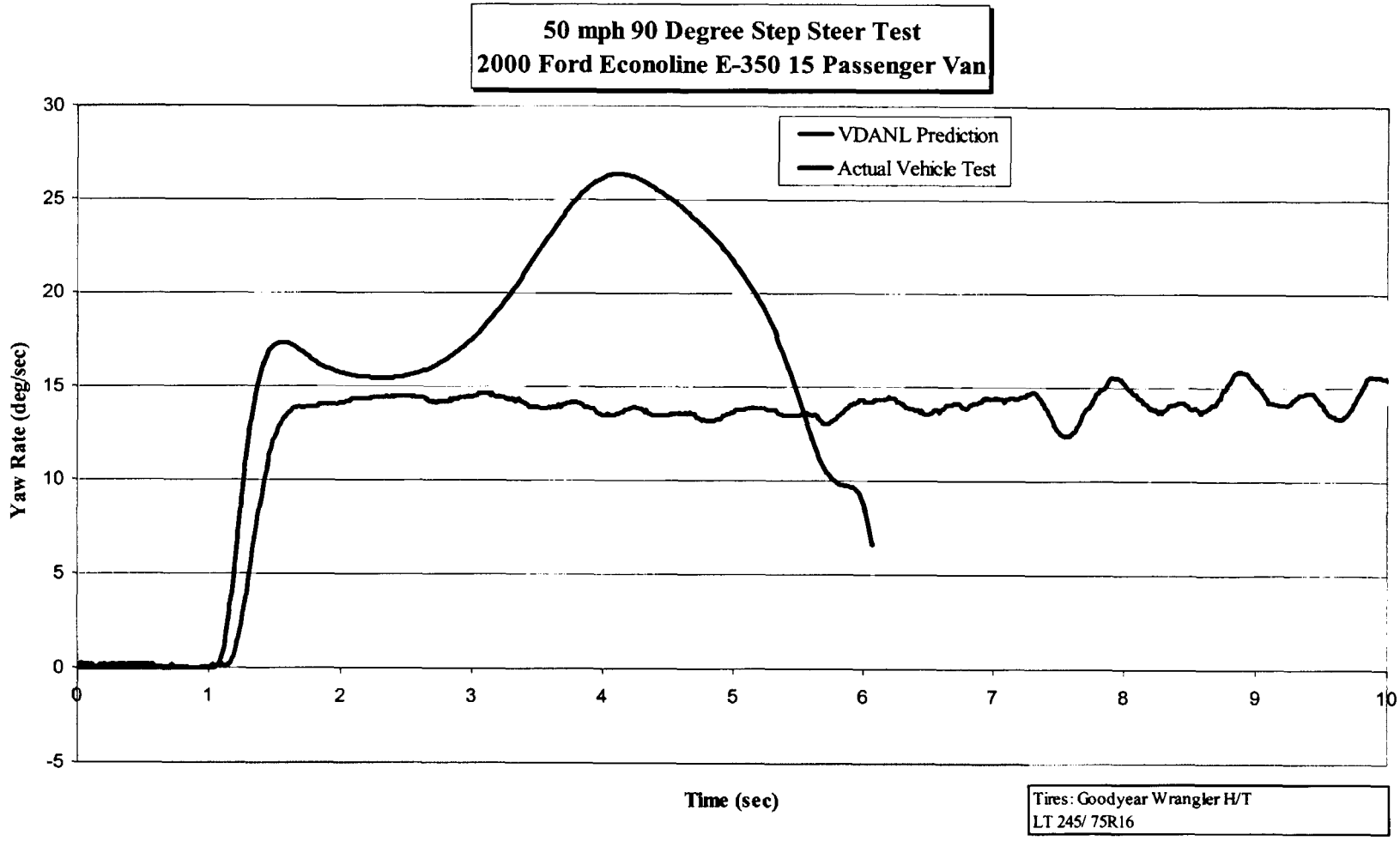
- 90 degrees of steer input at 50 mph
- 180 degrees of steer input at 30 mph
- 270 degrees of steer input at 25 mph
- 270 degrees of steer input at 30 mph

VDANL Fails to Make Correct Predictions

These Maneuvers Were Not Chosen by Ford Because of Their Mainstream Acceptance for the Evaluation of Vehicles But Rather Because They Were Easy to Simulate Using VDANL

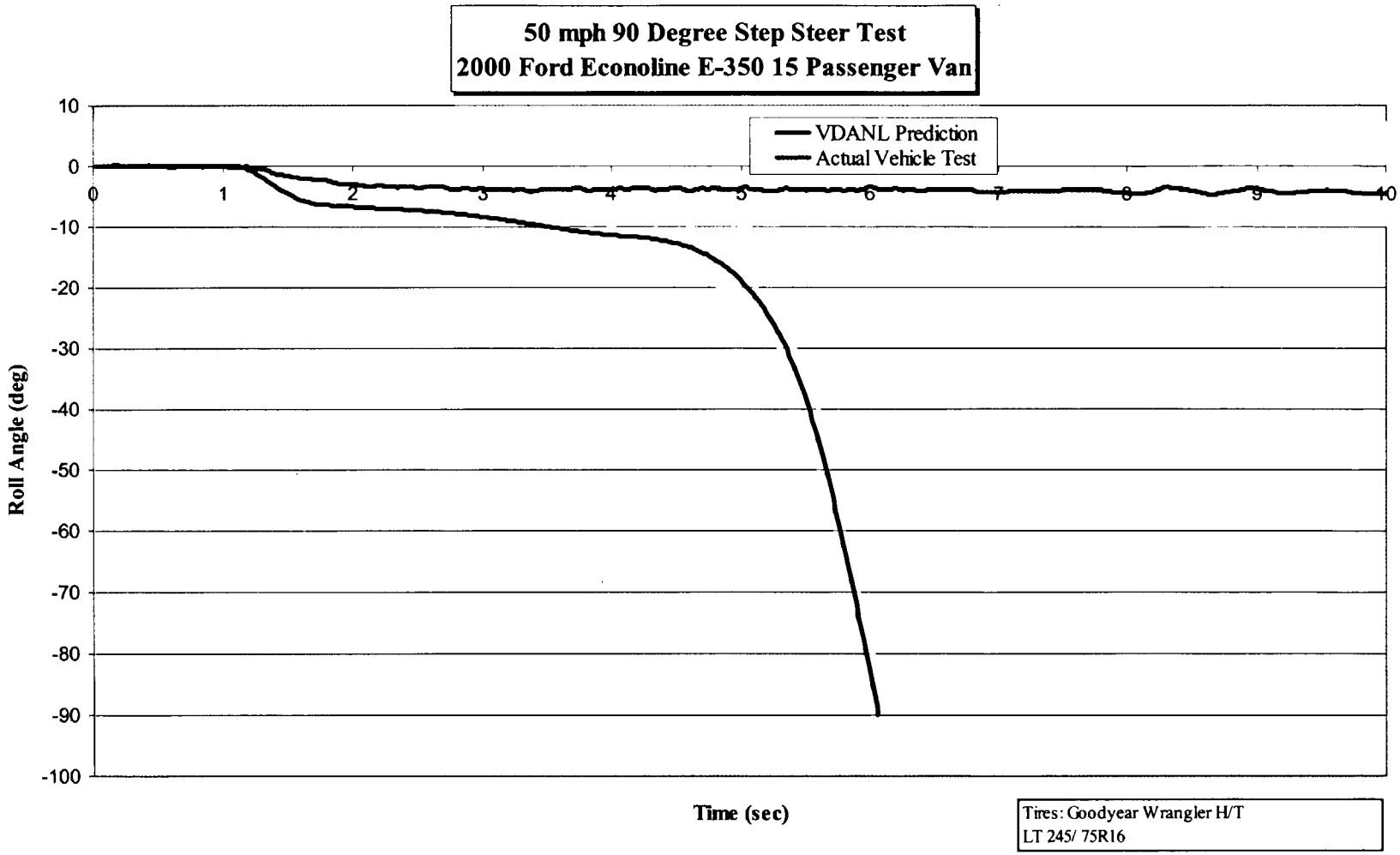
Comparison of Yaw Response

90 Degree Step Steer Test at 50 mph



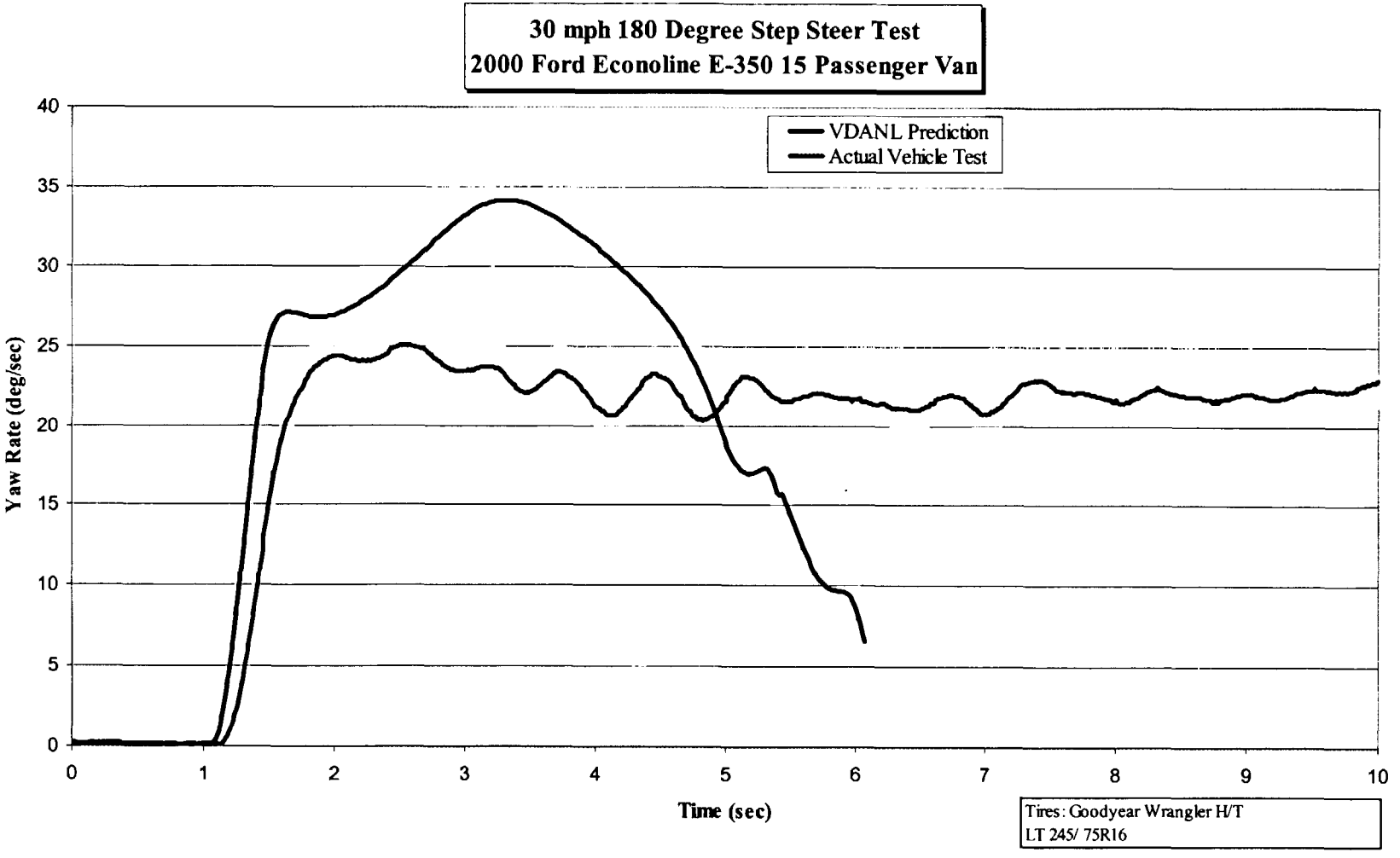
Comparison of Roll Response

90 Degree Step Steer Test at 50 mph



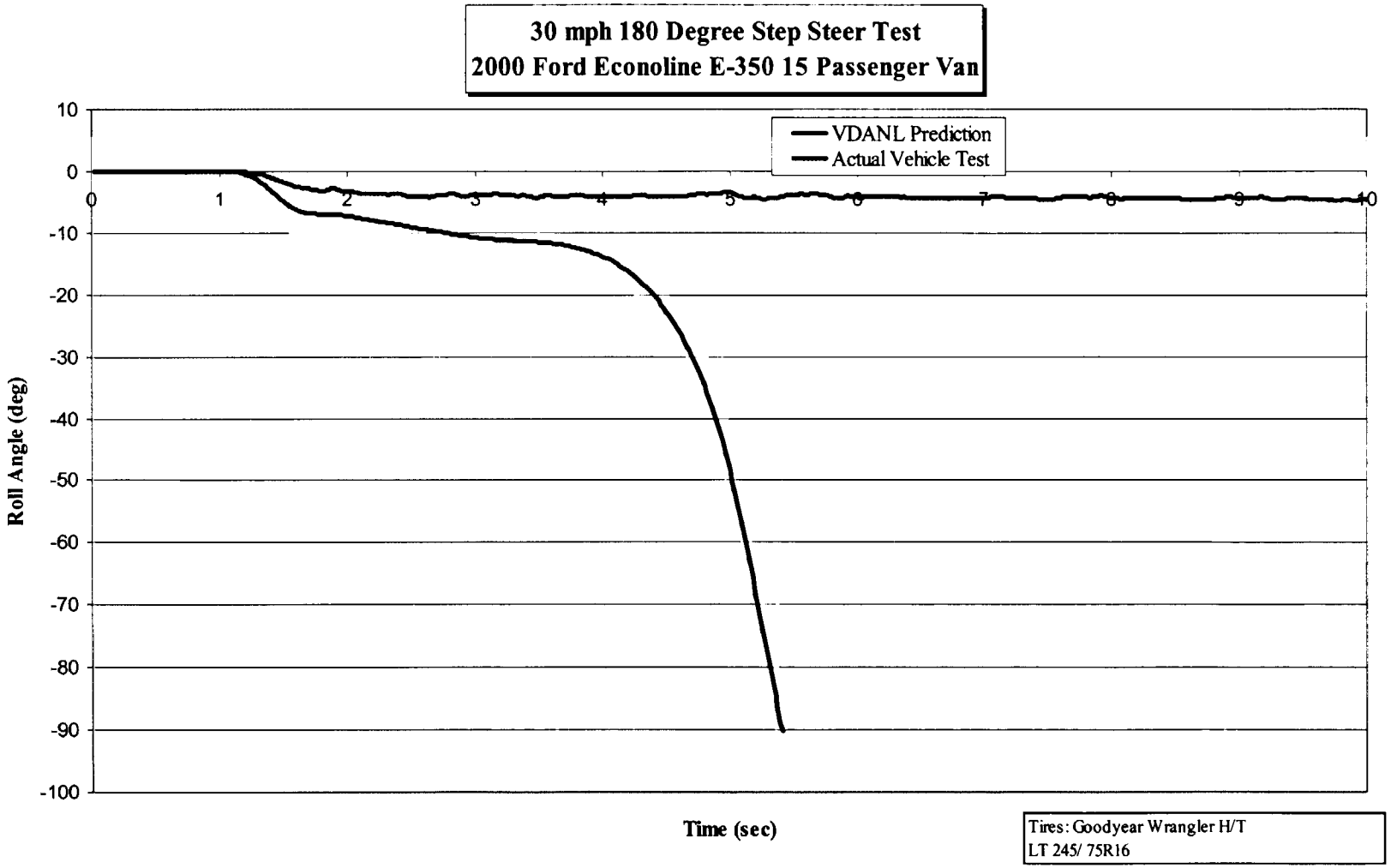
Comparison of Yaw Response

180 Degree Step Steer Test at 30 mph



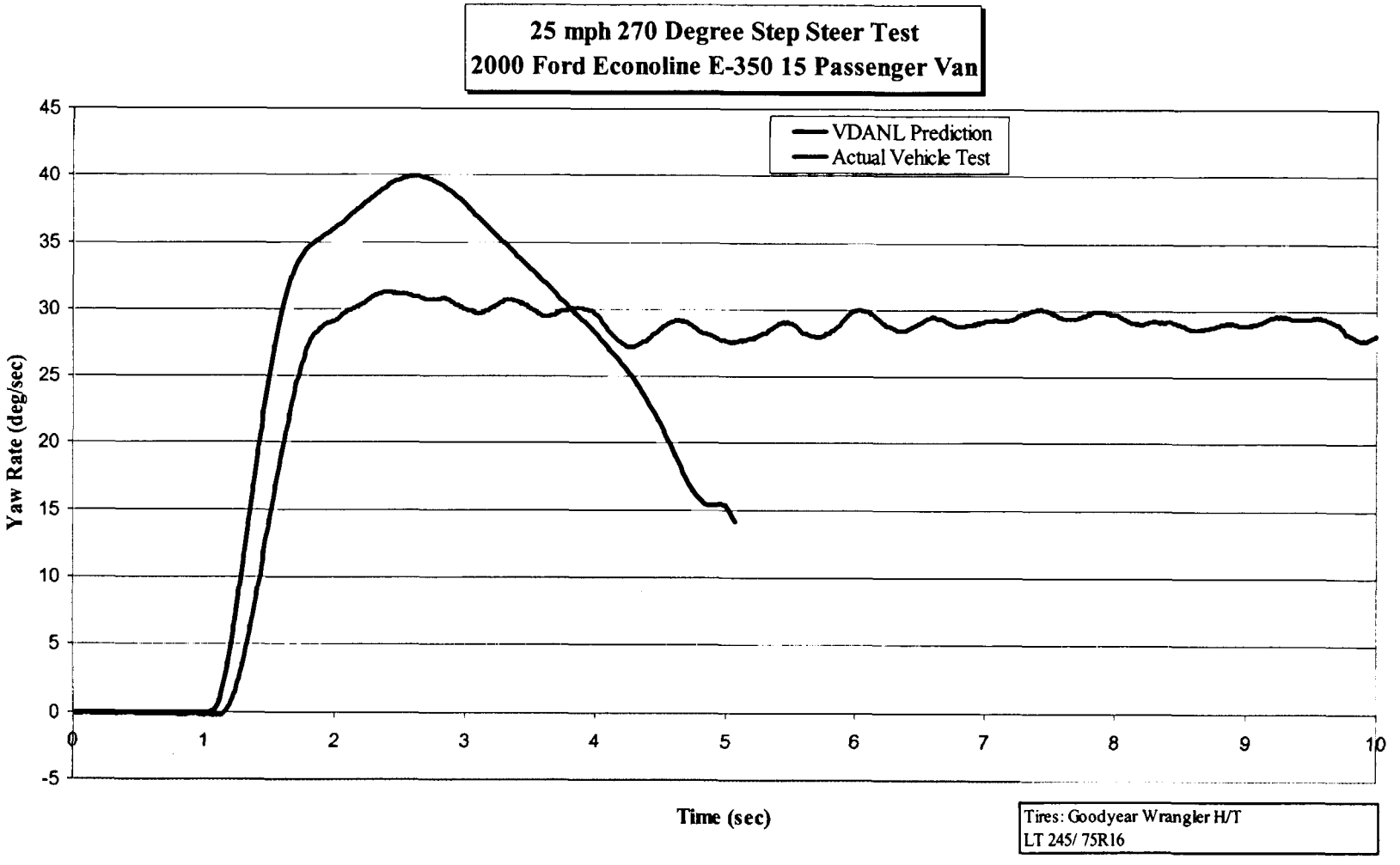
Comparison of Roll Response

180 Degree Step Steer Test at 30 mph



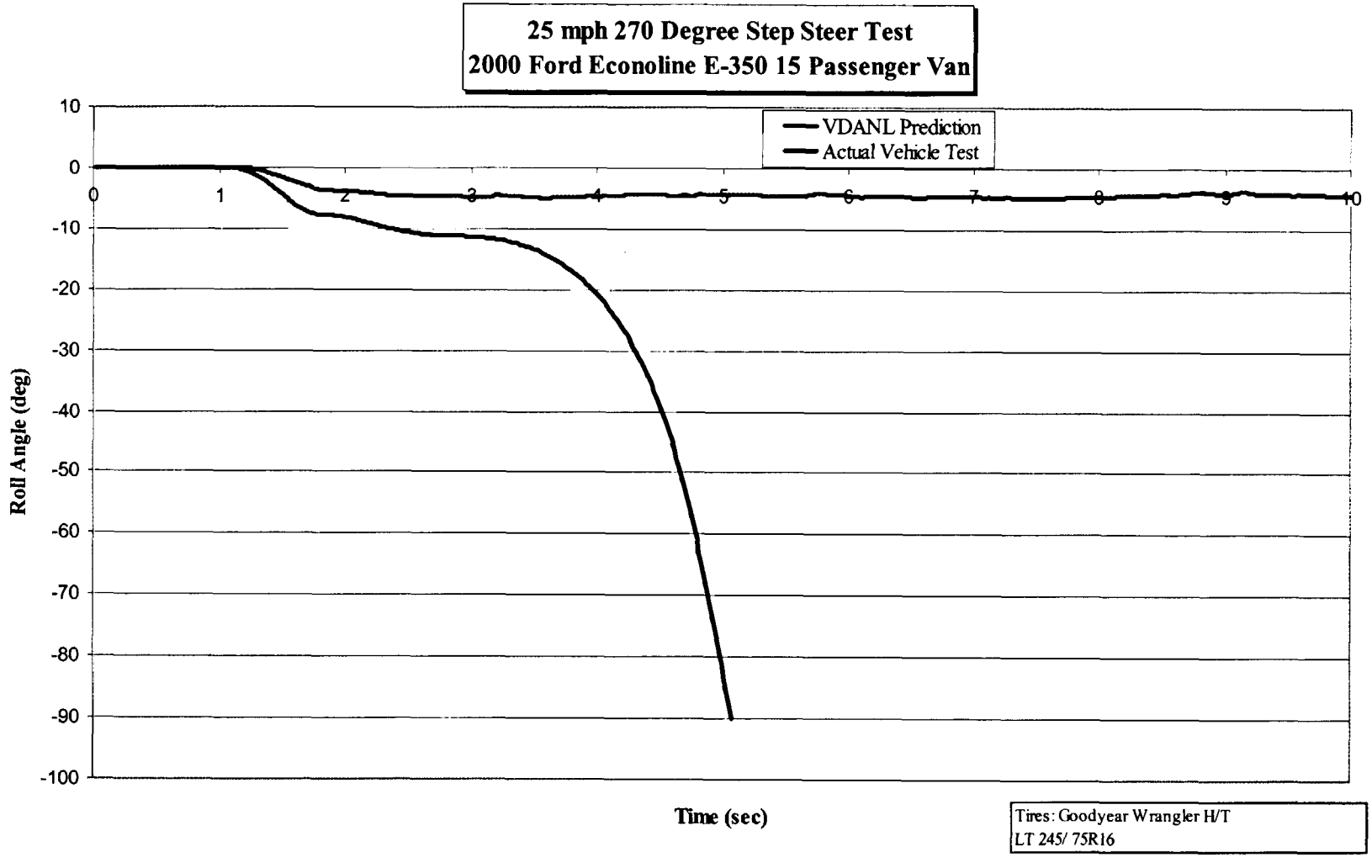
Comparison of Yaw Response

270 Degree Step Steer Test at 25 mph



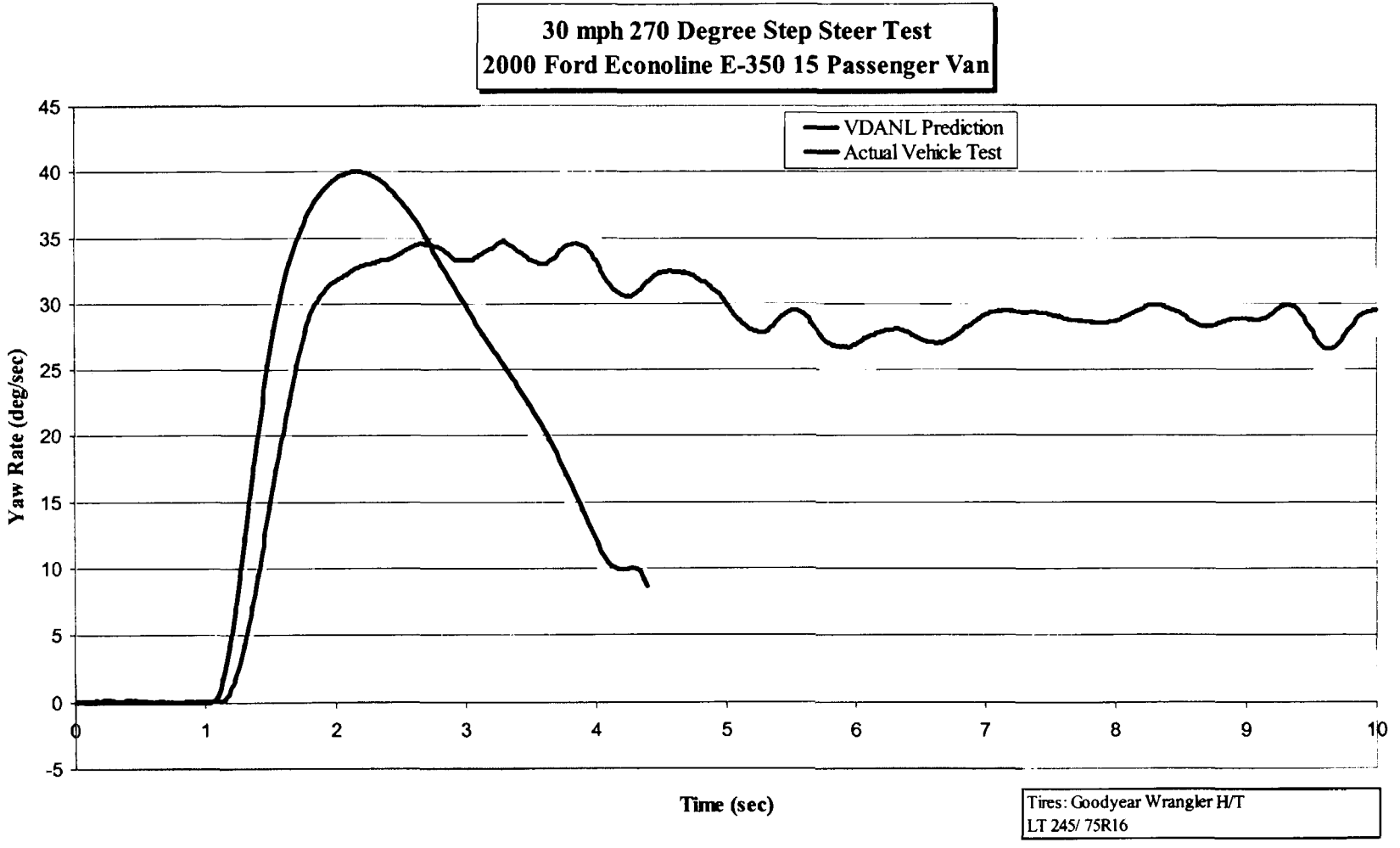
Comparison of Roll Response

270 Degree Step Steer Test at 25 mph



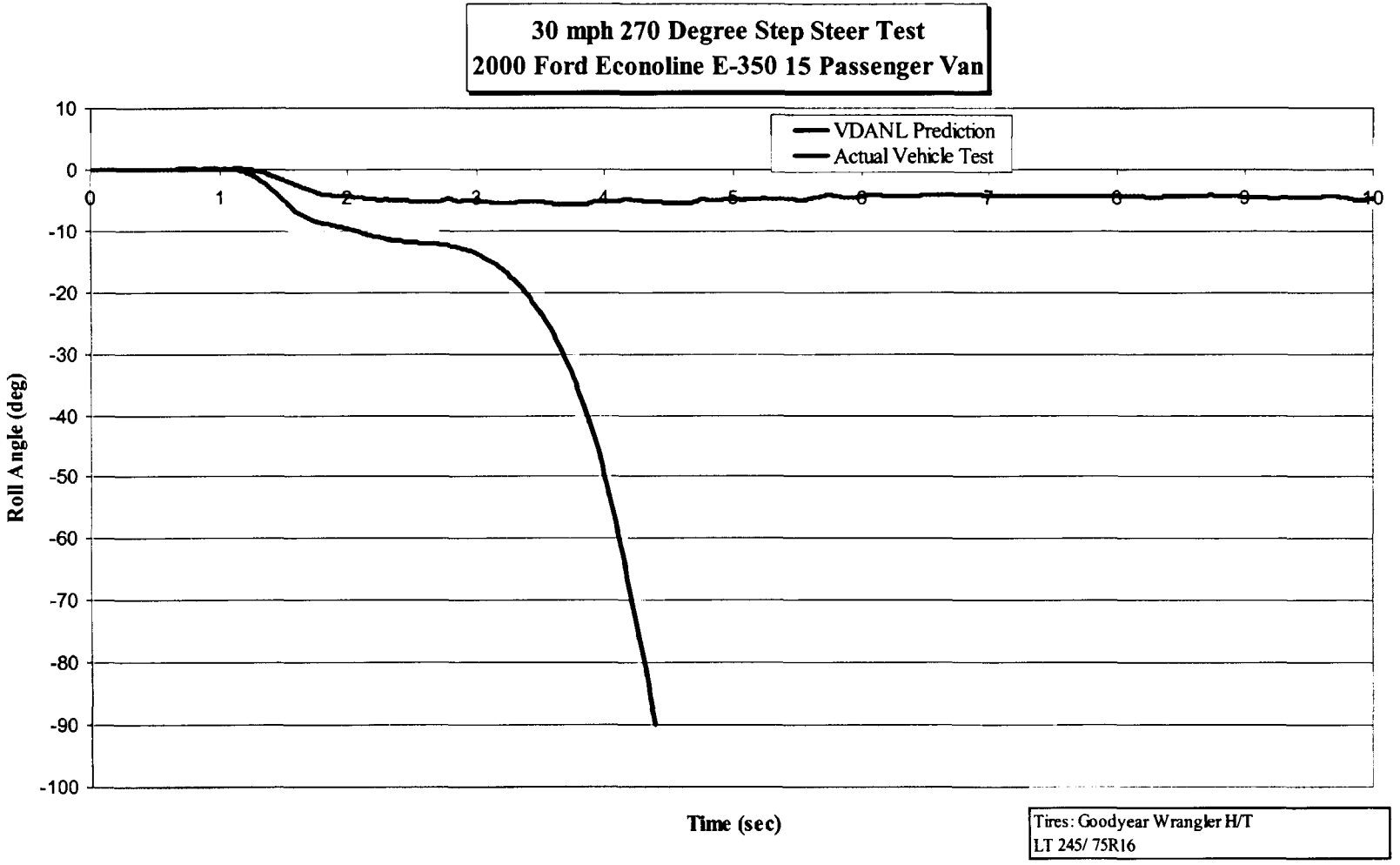
Comparison of Roll Response

270 Degree Step Steer Test at 30 mph



Comparison of Yaw Response

270 Degree Step Steer Test at 30 mph



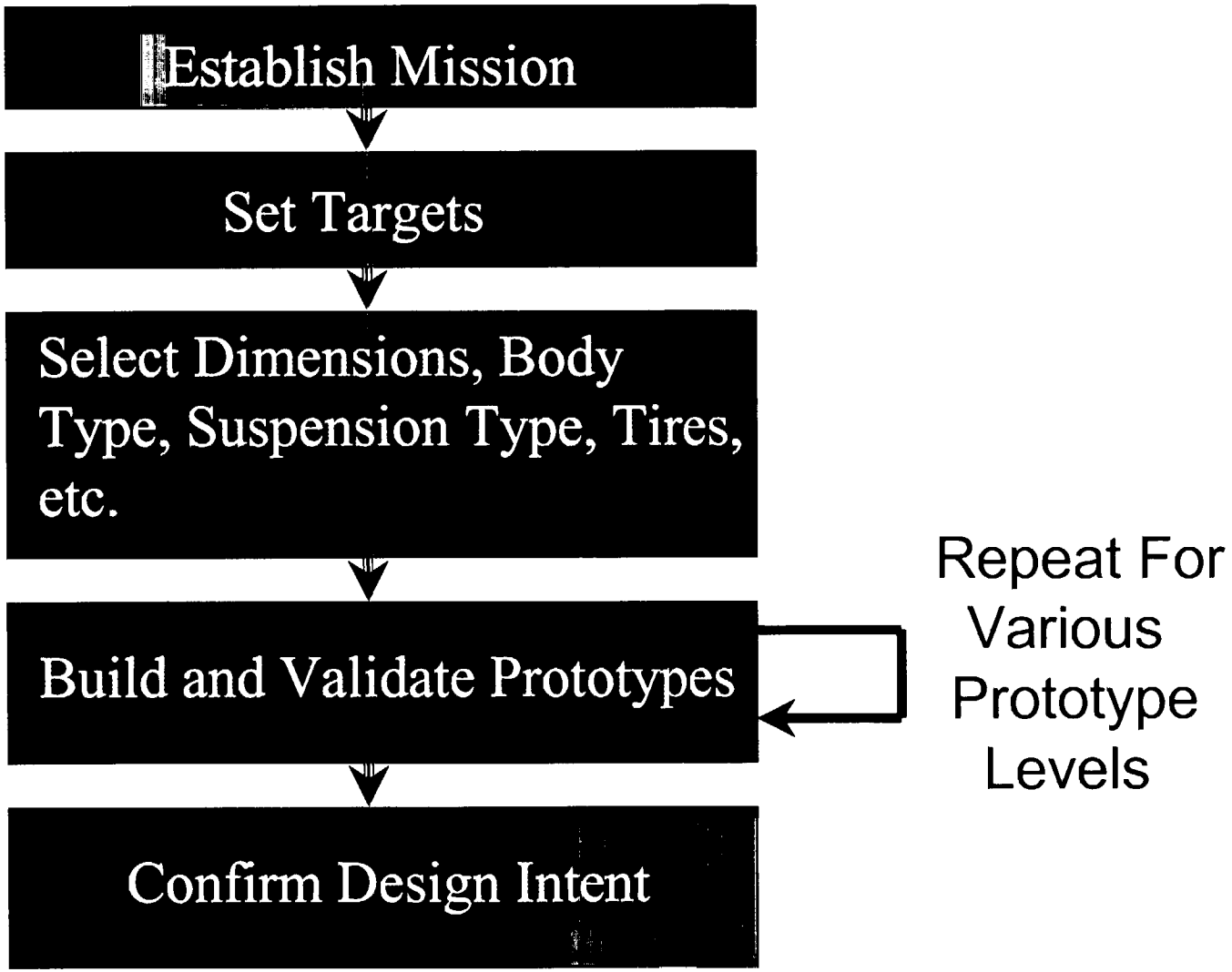
Video of all test runs and simulations

The Data Confirms That VDANL Fails to Make Correct Predictions

QUESTION:

How Did Ford Ensure That Its Fifteen-Passenger Vans Were Safe For Steering, Handling, and Resistance to Rollover?

Ford's Vehicle Design Process



On-Track Dynamic Tests

- P6-101 – Evaluation of Vehicle Handling
- Ensures the vehicle is controllable, predictable, and forgiving under a variety of conditions
- Vehicle performance is evaluated in both limit and sub-limit handling ranges
- Both open loop and closed loop tests are performed
- Expert and non-expert evaluators are used to assure vehicle meets performance objectives
- Judgment is used to assure that a design has a margin of safety. This protocol suits that purpose but is not suitable for use as a standard or single self sufficient test of rollover immunity

P6-101 Acceptance Criteria

- The vehicle should be controllable, predictable, and forgiving in limit and sublimit maneuvers
- The capacity of the vehicle should exceed reasonable driver demands
- Vehicle must have a margin of safety

Show P6-101 video

P6-101 Tests are State-of-the-Art and Are Similar to Those Used by Other Vehicle Manufacturers

Isuzu	Toyota	Land Rover
GM	Nissan	Daimler/Chrysler

In Summary

- Ford agrees that the center of gravity of all vans will rise with occupant loading
- Ford agrees that the longitudinal location of the center of gravity of all vans will move rearward with occupant loading
- Ford agrees that drivers should be aware that all vehicles handle differently when fully loaded
- Ford agrees that drivers and all passengers should be properly restrained

Ford's Conclusions on VDANL

- Ford disagrees with the adoption of a computer simulation model such as VDANL as a method by which vehicle dynamic performance can be measured and regulated
- Validation experiments confirm that VDANL is not a valid predictor of actual vehicle performance, especially in severe handling maneuvers
- Ford disagrees with the use of open loop maneuvers such as slowly increasing steer and reverse steer maneuvers as a standard by which a vehicle's resistance to rollover can be evaluated unless they achieve acceptable reliability, repeatability, objective metrics, and relevance to causes, conditions, and circumstances of crashes.

Ford's Conclusions on Fifteen-Passenger Vans

- Ford's fifteen passenger E-series vans were properly designed and tested and possess appropriate steering, handling, and stability characteristics for vehicles of its class and type
- Ford fifteen passenger E-series vans were designed to accommodate a full occupant load and, when loaded, possess appropriate steering, handling, and stability characteristics